Peer Effects in Art Prices

(Preliminary and incomplete)

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Abstract

Art is quite often considered as an investment. However, the prices for some of the pieces are not easy to predict. The reputation of the artists and their social connections can play a significant role in determining the prices of their work. I check the hypothesis of possible positive effect on the prices of art pieces when the artist is connected to higher valued or more famous peer. I base my results on the network of the abstract artist, for which it is sometimes too difficult to distinguish between good and bad work, and the prices of their works in the last 15 years at Sotheby's auctions. The preliminary results suggest that the consumers are willing to pay more for a particular artist's work, once this artist is connected to a more valuable set of peers. The auctioneer predictions exhibit opposite trend, suggesting possible substitutability of the works of connected artists.

1 Introduction

Art is receiving an increased attention in recent years as a possible investment. Art is often attributed to the category of so-called passion investment, which also includes

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jewelry, antiques, classic car, wine, etc. Passion investments are assessed to amount to 6% of total wealth (The Wall Street Journal, 2010), and the high-net-worth investors allocate globally around 17% of their cash to art (World Wealth Report 2013). According to Knight Frank Luxury Investment Index 2014, the 10-year capital appreciation of art is among highest and equal to 226%[1]. The estimation of the real returns in existing literature varies, depending on the methodology, time period and data used. For example, Goetzmann (1993) reports an average annual real return on oil paintings of 3.8% for the period between 1850 and 1986, with returns around 15% after 1940. Mei and Moses (2002) calculate the return of 4.9% for 1875-1999, with 8.2% after 1950. Renneboog and Spaenjers (2013) are more careful in their estimation with 3.97% over the period 1957-2007.

However, some of these results show the underperformance of art in comparison to the other types of investments. Moreover, the volatility of the prices on the art market is rather high. The attractiveness of the art market is, therefore, cannot be explained by the investment purposes. Global art and antique sales are steadily high in the last several years and are close to 50 billion Euro (with the exception of 2009 crisis)[2]. Buying pieces of art is also a popular tendency among high earners. Owning the work by a famous artist may help to strengthen a status in the society. Creating one's own collection can yield additional respect for their owner. The attractiveness of the art market in comparison to the other luxury items, as stated in the World Wealth Report 2013, is likely "driven by auction house sales, the art market is lively compared to other categories that are characterized more by inheritance and private sales". Approximately half of the art sales are made via auctions (McAndrew 2010), the rest are privately traded, mostly via art dealers. The auction prices are the ones who set the benchmark for the art prices in general.

In the literature, discussing art pricing, the following standard set of variables is usu-

[1]Consult here for more details.
[2]European Fine Art Foundation report

ally used as determinants of the price: artists' characteristics, works' characteristics, such as medium, authenticity, attribution, size, and topic, as well as the sales characteristics, such as a date and a place. Artists' reputation is usually included, however, it is not always clear, how to account for it. Renneboog and Spanjers (2012) include a dummy for mentioning of the artist in the classic art history textbook "Gardner's Art Through Ages" and a dummy of exhibiting at Dokumenta in Kassel.

This paper explores one important determinant of the art price formation that is potentially missing in the existing analysis, namely the artists' connections. I believe that connections can influence in two ways. First of all, following the classical peer effect logic, artists' links are influencing the development of artists' style and quality of the works. But also the prices of the work of one artist may be driven by the prices of the connected artists. If the artists worked together or were connected by the same movement, it is likely that their works will resemble some similarities and may get similar prices on the market. Alternatively, the demand for some artist's works may increase, increasing the price, if the works of connected to them artist are not available or too expensive. The famous film about street artist Banksy, "Exit through the Gift Shop", also depicts, how connections can attract high demand and big money to quite mediocre pieces of art. The paper uses the data on abstract movement artists and their works, collected especially for this project from the open resources. Abstract art is, along with contemporary art, among the movements, for which the price is especially difficult to determine, and hence, exploring the new channels of price formation may help to understand it better.

I apply the peer effect model introduced by Manski (1993) to the panel data on the prices of abstract artists' work sold at Sotheby's in 2000-first half of 2015. Although the model is modified to be applied to the panel data, and to use price as an individual outcome variable and average price as an endogenous variable of the connections, the identifying assumptions of Bramoullé et al. (2009) are still valid. The network is required to have intransitive triads for the model without the correlated effect and the

connections of length 3 for the model with correlated effects. This means that there should exist two artists that are not connected directly, but via one more artist (or two). These assumptions are plausible for most of the networks, and for the network of abstract artists in particular.

The paper is organized as follows. Section 2 discusses the proposed peer effect model and suggested estimation method. Section 3 introduces the data and provides some of the descriptive analysis. Section 4 provides the empirical results. Section 5 concludes.

2 Model

I have the sample of all works sold at Sotheby's for all of the artists in the sample, for $i \in [1, I]$ being an artwork from the whole set, $j \in [1, J]$ being an artist, created the work. In order to estimate the effect of being connected to other artists on prices of own work, I am proposing the model of peer effect, similar to Manski (1993) and Bramoullé et al. (2009), with the slight appropriate modification:

$$P_i^j = \alpha_0 + \alpha_1 t_i + \beta_0 Z_i + \beta_1 X_j + \beta_2 \sum_{l \neq j} G_{jl} X_l + \gamma \sum_{l \neq j} G_{jl} \bar{P}_l + \nu_j + \epsilon_i^j \qquad (1)$$

Some comments on the model ingredients are necessary.

P_i^j - price of the piece i by artist j. The prices are normalized as will be discussed in the next section.

Z_i - are the characteristics of the painting, that may include type of the work, size, possibly attribution to an artists' important period, provenance or exhibition history[3].

X_j, X_l - are the characteristics of the artists, such as particular style, major work type (paintings, sculpture etc.), country of birth and living, years active, possibly the total amount of works produced.

G_{jl} - is adjacency matrix with $1/n_j$ in the jl cell, if an artist j is connected with an artist

[3]The variables will be discussed in details in later sections

l, with n_j being the total number of connections of an artist j. Note that, although all the links are reciprocal in this particular setting, the matrix is not symmetrical, since the total number of friends is different.
ν_j - are the unobserved effects of the artists.

Here β_2 represents exogenous effect, how the similar characteristics of the connections influence the outcomes, γ is endogenous effect, showing how the outcomes of the connections may influence the outcome of the individual, ν_j are the unobserved characteristics of particular painter in the panel.

The presence of individual unobservable effect creates additional issue for the identification of the endogenous effects.

Potentially, the correlated effects can be also present in the model, making the smaller group within the network to behave similarly due to the unobserved similarities of the group. However, the network used in this paper is rather small, and the potential similarities of the subgroup can be captured by observed characteristics, such as the country of origin or/and work, the group affiliation etc. In more general setting the correlated effects problem can be dealt with by applying the local differences, averaging over the first level connections' outcome variables. The identification of endogenous effect is then achieved by the presence of links of the length 3 or more, and so $G_{jl}^3 X_l$ can be used as identifying instruments for the endogenous covariates.

Since the network is held constant in the panel, the fixed effects model, that is more suitable from the empirical point of view, is not applicable, as then the endogenous effect cannot be identified. So either the unobserved individual effects should be treated by random effects analysis or Hausman and Taylor type models should be used.

Both possibilities are plausible, depending on the explanation of assumptions one believes in. The unobserved individual effects in our empirical could represent the level of talent of the particular artist, his/her popularity, as well as characteristics not included

or missing in the vector of covariates attributed to the artist that could influence the outcome variable. The level of talent and some potential covariates are more likely to be uncorrelated with explanatory variables. The popularity is, however, possibly correlated with one of the explanatory variables, in particular, with the characteristics and outcomes of the connections. In this case, the random effects will produce inconsistent estimators of all parameters, and the Hausman and Taylor type models are more suitable for this particular setting. It is, however, more computationally demanding, and once the correlation is absent, the random effects are preferable.

2.1 Hausman and Taylor type models

If it is suspected that individual unobservables are correlated with the explanatory variables and time-constant[4] variables are of interest, as was already mentioned, neither fixed effects nor random effects are suitable for the analysis.

For now, I will ignore the correlated effects for simplicity of explaining the estimation approach. I will give a note on adding the correlated effects in the model later in the paper. First, I divide all explanatory variables into two vectors: time-variant $\boldsymbol{Z_i^j} = \{t_i, Z_i^j\}$ and time-constant $\boldsymbol{X_j} = \{1, X_j, \sum_{l \neq j} G_{jl} X_l, \sum_{l \neq j} G_{jl} \bar{P}_l\}$. I follow Hausman and Taylor (1981) approach and partition both vectors as follows: $\boldsymbol{Z_i^j} = (\boldsymbol{Z_{i1}^j}, \boldsymbol{Z_{i2}^j})$ and $\boldsymbol{X_j} = (\boldsymbol{X_{j1}}, \boldsymbol{X_{j2}})$ where $\boldsymbol{Z_{i1}^j}$ is $1 \times K_1$, $\boldsymbol{Z_{i2}^j}$ is $1 \times K_2$, $\boldsymbol{X_{j1}}$ is $1 \times J_1$, $\boldsymbol{X_{j2}}$ is $1 \times J_2$ and the following assumptions are fulfilled:

$$\mathbb{E}(\boldsymbol{X_{j1}} \nu_j) = 0 \quad \text{and} \quad \mathbb{E}(\boldsymbol{Z_{i1}^j} \nu_j) = 0$$

Additionally, the following assumption is necessary:

$$\mathbb{E}(\epsilon_i^j | \boldsymbol{X_j}, \boldsymbol{Z_1^j}, \ldots, \boldsymbol{Z_{w_j}^j}, \nu_j) = 0, \quad i = 1, \ldots, w_j$$

[4]Note, that notion of time is used here not in the direct sense, but rather follows the conventional terminology of panel data analysis. Time here denotes each time one of the works was auctioned.

with w_j being the number of works of artist j in the sample.

We can then rewrite the original model in a simpler way:

$$P_i^j = \beta Z_i^j + \alpha X_j + \nu_j + \epsilon_i^j \tag{2}$$

where $\beta = (\alpha_1, \beta_0)$ and $\alpha = (\alpha_0, \beta_1, \beta_2, \gamma)$.

Note that under assumptions in this subsections the time-constant variables are likely to include the outcome variable of friends, which are endogenous in the model. Therefore, the vector of instruments necessary to apply HT approach should additionally include an identifying instrument for the endogenous peer effect, which is the exogenous characteristics of friends of friends, following Bramoullé et al. (2009). The estimation procedure is as follows:

- First, the fixed effects approach is applied, which gives consistent estimation of the coefficients of the time-varying variables $\hat{\beta}_{FE}$.
- Using the estimator of the first step, calculate the residuals as follows:

$$\hat{d}_j = \bar{P}^j - \hat{\beta}_{FE}\bar{Z}^j = \alpha X_j + \nu_j + \bar{\epsilon}^j \tag{3}$$

- Now, estimate 3 with a 2SLS approach. The standard vector of instruments in Hausman and Taylor approach is $[\boldsymbol{Z_{i1}^j}, \boldsymbol{X_{j1}}]$. To be able to identify the endogenous peer effect, I suggest adding $\sum_{l\neq j} G_{jl} \sum_{k\neq l} G_{lk} X_k$ to vector of instruments.
- Using the residual variance σ^{*2} from the previous step and estimator of σ_ϵ^2 from the first step, calculate $\sigma_\nu^2 = \sigma^{*2} - \sigma_\epsilon^2/\bar{T}$, where $\bar{T}$ is a harmonic mean of T_j's. And compute the weighting coefficients for GLS as:

$$\theta_j = 1 - \left(\frac{\sigma_\epsilon^2}{\sigma_\epsilon^2 + T_j\sigma_\nu^2}\right)^{0.5}$$

- Finally, the following transformations are made: $P_i^{j*} = P_i^j - \theta_j \bar{P}^j$, $Z_i^{j*} = Z_i^j - \theta_j \bar{Z}^j$, $X_j* = X_j - \theta_j \bar{X}$. IV regression of P_i^{j*} on Z_i^{j*}, X_j* are performed, using the vector of instruments $[Z_i^j - \bar{Z}^j, Z_{i1}^j, X_{j1}, \sum_{l \neq j} G_{jl} \sum_{k \neq l} G_{lk} X_k]$

2.2 Alternative approach

The Hausman and Taylor approach is computationally challenging, and the number of artists in the sample is not very high with the number of observations for each of them varies a lot, therefore, the alternative approach, avoiding usage of panel data structure is also proposed. The artists dummies are used in this case, combined with the standard 2SLS proposed by Bramoullé et al. (2009) following Lee (2003) approach. The model is then as follows:

$$P_i^j = \alpha_0 + \alpha_1 t_i + \alpha_2 AD_i + \beta_0 Z_i + \beta_1 X_j + \beta_2 \sum_{l \neq j} G_{jl} X_l + \gamma \sum_{l \neq j} G_{jl} \bar{P}_l + \epsilon_i^j \qquad (4)$$

with AD_i - set of artists' dummies.

The 2SLS is then conducted with $\sum_{l \neq j} G_{jl} \sum_{k \neq l} G_{lk} X_k$ as an instrument for an endogenous variable $\sum_{l \neq j} G_{jl} \bar{P}_l$.

The two proposed approaches should yield comparable results since both of them provide consistent estimators. I do not prove the consistency of the resulting estimators in this paper, but it logically follows from the proofs in Hausman and Taylor (1981) and Lee (2003).

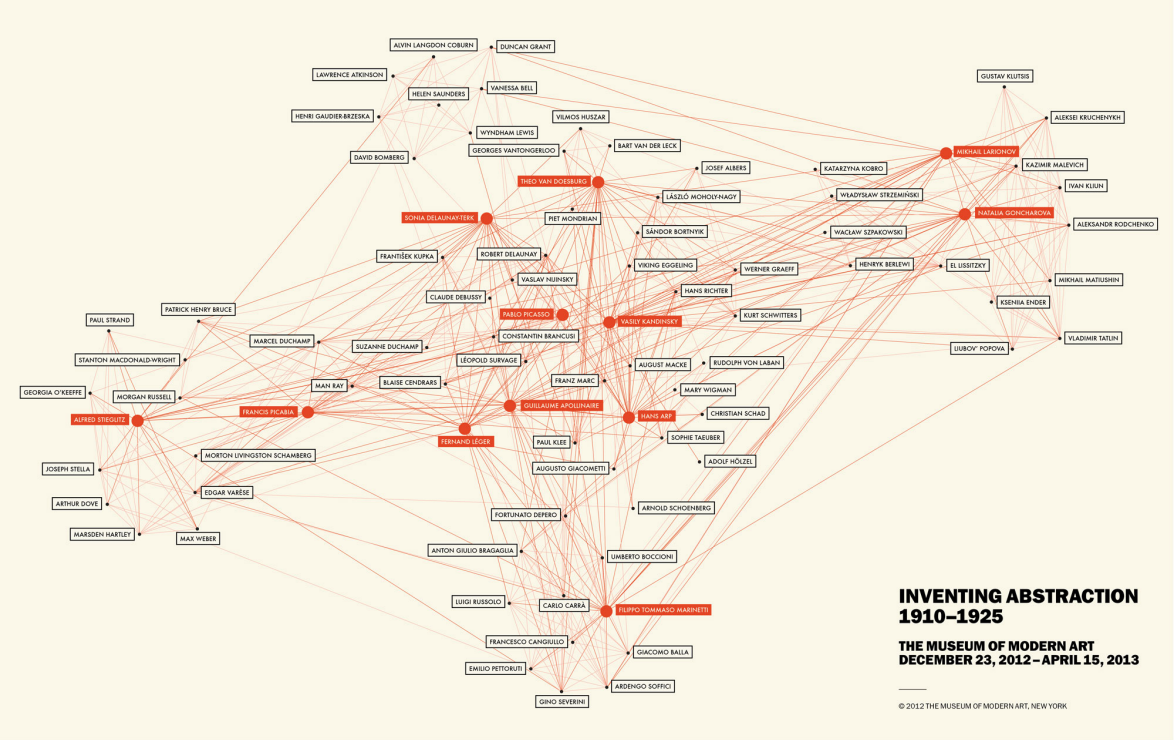
3 Data description

The data in the paper consists of several parts: the data on the artists' connections, the data on the artists' characteristics and the collection of the prices for the artists' work sold at the auctions at Sotheby's since 2000.

The network data is taken from the diagram, prepared by the group of researchers for

the exhibition "Inventing Abstraction, 1910-1925" at the Museum of Modern Art, New York in December 2012-April 2013.[5]

Figure 1: Network of abstract artists



This diagram represents documented relationships among the artists, who played significant roles in the development of the new art language. The whole list of the artists can be found in the Appendix C. The diagram was manually transformed into adjacency matrix, with $1/n_i$ at the ij cell, if the artist i is connected to the artist j, and n_i is the total number of connections of the artist i. Moreover, I collected additional information about art groups at the time, such as Der Blaue Reiter (The Blue Rider), De Stijl, etc., to be able to distinguish between the links of different intensity. Table 1 shows the number of artists affiliated with the groups and the number of artists worked in the particular country. Some of the artists worked in more than one country, I included each

[5] An interactive detailed network can be found online at the MOMA website.

of them if it was mentioned either on the official website of the MOMA exhibition or in "A Dictionary of Twentieth-Century Art"(1999) by Ian Chilvers.

Table 1: Countries and groups allocation

Countries	Groups
France (30), USA (20), Germany (18), Russia (18), Italy (15), Switzerland (9), England (8), Poland (5), Spain (4), The Netherlands (4), Hungary (3), Romania (2)	Der Blaue Reiter (7), Puteaux Group (6), De Stijl (4), Union of Youth (4), Donkey's Tail (3), Supremus (3), 291 Gallery (3), Jack of Diamonds (2), Societe Anonyme (2), Bloomsbury group (2)

The existing network determined the sample of the artists used for the analysis. However, several of the names from the list were not included in the analysis. Those are people important for the abstraction movement, but they were not creative artists, such as, for example, Guillaume Apollinaire, who was a writer and an art critic, or Claude Debussy, who was a composer. Therefore, the auctioned items related to these people are more likely to be personal items or similar. There are 83 artists in the initial list, 11 of which were eliminated.

The set of artists' characteristics were collected from different biographical sources. Among those characteristics are the following: years of life and years active, the country of birth and the country, where the artist was more active, main artistic mode (paintings, sculpture, photographs etc.), particular major style inside of abstractionism; if available, approximate amount of known works and most valuable periods to be able to determine the rarity of the works.

The price dataset was collected specially for this paper from the Sotheby's auction house website. The special program was written to obtain all the lots for each of the artists, auctioned at Sotheby's and both sold and not. The data were available for the auctions that took place from the year 2000, earlier lots are not available online. For

each lot the following information is usually available: an estimated price of the work, whether it was sold and the price, which lot was sold, date of creation, type of work, size, provenance, history of exhibitions, although the descriptive information is missing in quite a lot of cases. There might also be some additional catalogue notes, including conditions, authenticity information, etc. However, not all of this information can be included in the model. Part of the description is very difficult to re-translate into quantitative variables.

There are several data issues that should be pointed out. **First of all**, for now only the data from one auction house is used. This may cause some distortion of the results since I am not looking at the whole market situation, i.e. I am not controlling for the availability of the works of a particular artist in the other auction house at the same time. The full dataset will be collected in the future research, however, new programs should be written for each of the auction houses to scrap the data from their websites due to the different layouts.

Secondly, the types of works included in the sample are rather different, such as oil paintings, watercolours, lithographs, different types of sculptures, photographs etc. Including dummies for each of the type of the work is possible. However, the description is missing for almost 30% of the cases, hence, not all of the works can be attributed to a particular medium. Since most of the artists in the sample used different media in their work, so only some lots can be attributed to a specific medium used by the artists[6]. I am treating these lots as not attributed. However, buyers at the auction were aware of the type of work on sale. This missing information is likely to result in biased estimation. One of the solutions is to obtain the better dataset. However, it can be observed that most of the missing information corresponds to the sales in years 2000-2003. So the missing information problem can be partially dealt with by restricting the sales sample

[6]The online database The Art Sales Index could possibly provide a better quality data, I am currently writing the program to obtain it, and the new dataset will be used in the further extension of the paper.

for the years after 2003.

Thirdly, the prices are given in the local currency of the auction, which requires price adjustment not only for the inflation but also for the exchange rates. Most of the prices are in USD (43,3% of the lots), in GBP (42,3%), or EUR (13,6%). Several lots are in Swiss Franks, Australian, and Hong Kong Dollars. I use daily historical exchange rates to convert all of the prices into US Dollars. I then adjust prices by CPI of USD, taking the beginning of the sample, January of 2000 as a baseline of 1. In both nominal and real terms the most expensive transaction in my sample is "Garcon á la Pipe" by Pablo Picasso sold at Sotheby's New York in May 2004 for 104 million USD.

The total sample consists of about 12000 observation, however, not all of the observed lots were sold, and the sample used for the analysis is, therefore, smaller, and consists of 9857 lots.

Description of the sales

Table 2: Average prices

	Median	Mean	Standard deviation	Number of observations
All sold	20570	384000	2701223	9857
Sold after 2003	25550	463620	3041266	7686
Oil paintings	195800	1919583	6727491	1637
Watercolors	86040	396300	1238530	351
Drawings	27270	179300	824219	4166
Sculptures	43810	541300	3144502	225
Photographs	21900	91480	281245	389
Not attributed	11000	83191	545287	4103

It can be noticed from Table 2 that the prices are indeed different for the different media. The oil paintings are expectedly the most expensive, and the photographs have

the lowest prices. Drawings form the biggest group, with almost half of all the sales. Not attributed works amount to more than 40% of all sold lots, which is more than in a total sample. Judging from the distribution of the values of unattributed works, most of them are likely to be either drawings or photographs, and do not belong to the categories with higher prices. Hence, I can still analyse the full sample, including dummies for oil paintings, watercolors, and sculptures only.

Figure 2: Distribution of sales over the years

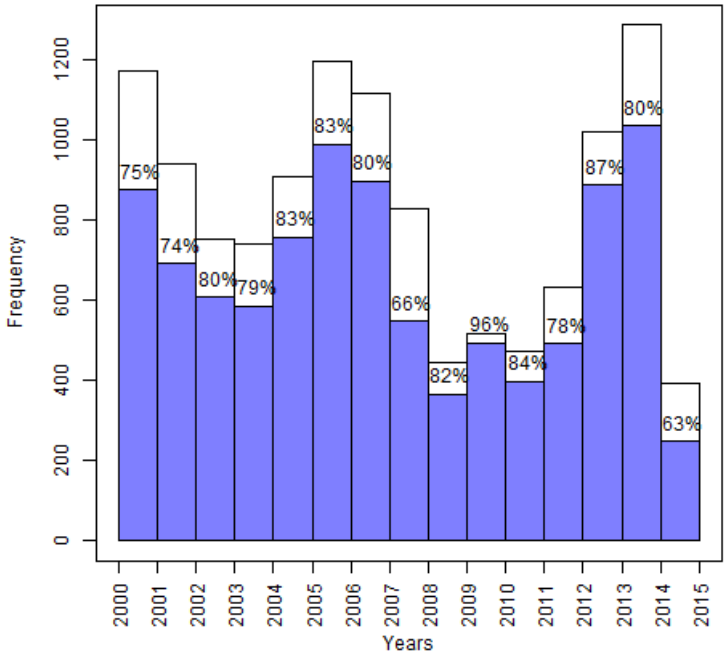


Figure 2 shows the distribution of the auctioned and sold lots of the observed time period. The number of lots in abstraction art varies during the observed time period with the biggest decrease around the 2008 crisis. The percentage of the lots sold in the first years after the crisis is, however, among the highest (82% in 2009 and 96% in 2010). In the recent years, the level of sales recovered to the pre-crisis year. Note, that the data

was collected in the middle of 2015, determining the low amount of sales in this years.

Table 3: Prices over time (in 2000 prices)

	Average	Sum	Maximum	Sold lots	Total lots
2000	181 916.44	57 121 761	10 064 195	314	421
2001	55 504.83	31 138 212	3 016 847	561	749
2002	97 233.27	67 090 953	5 634 195	690	938
2003	109 052.58	66 085 862	10 659 028	606	753
2004	497 636.84	291 117 551	116 695 313	585	740
2005	179 560.06	135 747 408	21 430 066	756	906
2006	300 164.66	296 562 685	114 225 355	988	1195
2007	430 133.71	385 399 804	36 309 073	896	1114
2008	704 978.33	385 623 149	50 360 523	547	826
2009	424 994.75	155 548 077	14 712 432	366	446
2010	374 195.48	184 478 373	12 049 552	493	515
2011	803 838.78	319 123 997	53 231 183	397	471
2012	700 985.01	343 482 657	56 631 229	490	632
2013	549 474.89	486 834 749	61 579 591	886	1018
2014	464 436.80	480 227 654	44 430 080	1034	1285
2015	400 162.95	99 240 411	18 688 892	248	392

Table 3 provides more details on the dynamics of the prices and sales of abstract art over the discussed period of time. The first four years of the observations show the relatively low total value of sales, as well as the average price of the lots. After that, the sales increased significantly with slight decline around after 2008. Demand and for abstract art auctioned during that period cannot be considered as homogeneous, therefore, year dummies should be included in the analysis.

Data also include the minimal and maximal expected prices of each lot, which is the

auction house estimate of a potential price before the beginning of the auction. In the cases, when the lots were sold, these prices are quite an accurate estimate of the final price with a correlation of around 95%. However, these prices don't help to predict, whether the lot will achieve the reserve price, set by auction and seller together. One of the expected prices can be used as an outcome variable to estimate the effect on the price formation, however, it will have a different meaning than the effect on the final prices of the lots, representing the market response. I will consider both possibilities in the empirical analysis.

Network characteristics

The network, as was already mentioned, consists of 83 artists. Table 4 gives some of the characteristics of the network.

Table 4: Network characteristics

Network statistics	Definition	Value
Average indegree	Average number of ingoing ties	12.84 (6.44)
Minimum indegree	Minimal number of ties	2
Maximum indegree	Maximal number of ties	28
Density	Proportion of existing ties in the network	0.1566
Transitivity	The ratio of the triangles and the connected triples in the graph	0.4629
Links from same country		0.8435
Links inside the group		0.0999

Links inside the group, if belonged to a group		0.2807

The network has quite a high number of average connections, more than 12. It is highly likely, that not all of the connections have an effect on the outcome variables, however, it is almost impossible to restrict the number of connections. One option is to put higher weight on those, working in the same country or affiliated with the same group. Most of the links formed between artists lived or worked in the same country for a significant amount of time. The share of the links in the same group is, however, rather small. Not all of the artists belonged to official groups, even though they belonged to a particular movement, whereas some of the artists had affiliations to several groups. Therefore, the group affiliation might be useful as a control variable of artists' characteristics, but not as an indicator of the tightness of connections.

The transitivity of the network is 46%, which is sufficient for the identifying assumptions to hold.

4 Empirical analysis

I am considering several scenarios in my empirical analysis. Recall, that not all of the lots were sold during the auctions. Unsold lots don't necessarily indicate the quality or importance of the work, but more likely to be a characteristic of the market situation. First, I am analysing the sample, excluding these observations. The results characterize the price formation determinants, but not describe the market situation in general. Unsold works are very relevant to understand, how the buyers value the works with particular characteristics. Therefore, I also consider the full sample, letting the price of unsold lots be equal to zero. Additionally, I am conducting the analysis of the full sample,

using the minimal and maximal estimated prices, established by the auction house, and, therefore, representing a possibly more objective value of the work. I expected the latter results to be similar to the results for the sample of only sold lots. However, the empirical analysis proved otherwise, which I will explain in more details in the course of this section.

4.1 Subsample of sold lots

As was described in Section 2, I am mostly relying on the modified version of Hausman-Taylor Type models. However, I also provide the results for the 2SLS procedure with artists' dummies, as described in 2.2. The estimation results for the subsample of sold lots can be found in Table 5. Note that the some of the exogenous characteristics of friends have slightly different meaning than own exogenous characteristics. The characteristics related to the works or the auction are not artist-specific, therefore, the average is used as artists' characteristics, which in a lot of cases has the meaning of shares. For example, averaging the dummy variable of oil paintings as a type of work gives the share of oil paintings among the works of the artist. Since most of the variables are either dummy variables or shares, use of logarithm of prices is more appropriate. To avoid the problem with the logarithm of zero, I take a logarithm of $Price + 1$.

Table 5: Results for sold lots

	HT	IV
Constant		3.4121$^{\bullet}$
Av.log price of friends' works	**0.8645*** **	**0.4538*** **
Artists' dummies		incl.
Work's characteristics		
Oil painting	2.1485***	2.1892***
Watercolor	0.9453***	0.8754***

Drawings	0.1946***	0.1923***
Sculpture	0.6152***	0.5325***
Signed	0.2005***	0.1944***
Sale's characteristics		
2008	0.3578***	0.3463***
2009	0.5409***	0.5436***
2010	0.7089***	0.6915***
London	0.5862***	0.5302***
New York	0.6299***	0.5802***
Artist's characteristics		
Germany	-0.0271	0.4131*
USA	-0.0671	-0.2108
Russia	-0.3955*	-0.7322***
Link's characteristics		
Share of oil paintings	3.1866	-2.9127
Share of watercolors	-0.5486	3.60977•
Share of drawings	3.6839***	1.4016•
Share of sculptures	-11.2321	9.0579
Share of signed	-0.6691	0.7366
Share of 2008	-1.2717	-8.6464**
Share of 2009	0.8975	15.8423**
Share of 2010	3.7417	-36.3713***
Share of London	-1.7103	0.2385
Share of New York	-1.0710	1.4047
Germany	0.0634	-0.5304
USA	0.8562**	0.8710***
Russia	-1.7922***	-1.2580***

*** - p-value < 0.001, ** - p-value < 0.01, * - p-value < 0.05, $^{\bullet}$ - p-value < 0.1

Both models detect the highly significant positive effect of the average prices of friends' works on the price of one's own work. The magnitude is, however, not very high. For example, the increase of friends' average price by 10000 USD will on average result in increase of 3000 USD. Most of the results are consistent across two methods for own characteristics, whereas the effect of the exogenous characteristics of connections differs. In particular, the IV regression detects a very high negative effect of share of friends' work sold in 2010. One possible explanation is the general market situation in 2010. The art marked didn't not recover completely after the 2008 crisis, and the number of sales went down, as was discussed in Section 3. The average price of sales in 2010 is lower than in following years, hence the higher share of 2010 sales suggest the cheaper set of works among friends. Hence, this effect is related to the endogenous peer effect. However, the Hausman-Taylor model does not support this finding. Note, that both models show the positive effect of the one's own work sale in all the crisis years I am controlling for. It probably suggests, that once the work got on the auction in these years it is more likely to be less risky since the share of sold lots in these years is very high, hence, the prices are slightly higher.

In Section 3 it was noted that most of the missing information in the sample is for lots that were auctioned in the period 2000-2003. I am, therefore, restrict my sample to the after 2003 sales to check, whether the results are stable in the better subsample. The estimation results are presented in Table 6.

Table 6: Results for sold lots, after 2003

	HT	IV
Constant		$3.8531^{\bullet}$
Av.log price of friends' works	**0.8179*** **	**0.3926*** **

Artists' dummies		incl.
	Work's characteristics	
Oil painting	2.1385***	2.1845***
Watercolor	0.9267***	0.9034***
Drawings	0.1339***	0.1350***
Sculpture	0.4762***	0.3970***
Signed	-0.0073	-0.0045
	Sale's characteristics	
2008	0.2160**	0.2011**
2009	0.4253***	0.4008***
2010	0.5629***	0.5436***
London	0.5929***	0.5507***
New York	0.5482***	0.5235***
	Artist's characteristics	
Germany	0.1372	0.1486
USA	-0.1825	-0.3001•
Russia	-0.1161	-0.6072**
	Link's characteristics	
Share of oil paintings	0.7454	-0.4430
Share of watercolors	2.4584	6.7982**
Share of drawings	3.0220***	0.6620
Share of sculptures	-11.5981	9.4014
Share of signed	2.5989	-0.1220
Share of 2008	-9.6161*	-9.4391**
Share of 2009	20.3077**	13.6115*
Share of 2010	-0.9464	-28.0462**
Share of London	-1.9372	0.7853

Share of New York	-1.4191	1.3778
Germany	0.4970	0.6033
USA	1.2969***	0.7846**
Russia	-2.1823***	-1.2936***
*** - p-value < 0.001, ** - p-value < 0.01, * - p-value < 0.05, • - p-value < 0.1		

It can be observed, that most of the results hold for the restricted sample. First of all, the positive effect of the average price of works of friends exists. The magnitude is slightly smaller than in the sample of all sold lots.

The Hausman-Taylor model is able to catch the same effect for the share of works of friends auctioned in 2009, as was observed in the sample of all sold lots for IV estimator. However, the respective effect for 2010 is not detected. IV estimator, on the contrary, provides the same evidence as before for these variables. In general, restriction of the sample is not changing the results of the estimation significantly.

4.2 Full sample

Letting the price of unsold lots be zero, I am now repeating the analysis for the full sample. The correlation of the final market price and the maximal estimated price is no longer as high as it is in the sample of sold lots, therefore, this price can be included in the analysis, as one of the covariates. It can serve as a proxy for the quality of the work and capture some of the work's and artist's characteristics, determining the price. The estimated effect of the other variables will have slightly different meaning than in the previous case, and will catch the effect on the success of the sale.

Table 7: Results for the full sample

	HT	IV
Constant		-6.8033
Log Max EP	0.6182***	0.6169***

Av.log price of friends' works	**1.2115****	**0.4886**
Artists' dummies		incl.
Work's characteristics		
Oil painting	0.1743	0.1958
Watercolor	0.0345	0.0292
Drawings	-0.1311**	-0.1268
Sculpture	0.3112	0.2799
Signed	0.6158***	0.6106***
Sale's characteristics		
2008	-1.4809***	-1.3565***
2009	0.4002•	0.312*
2010	1.8663***	1.9270***
London	-0.0038	0.0315
New York	-0.4963***	-0.5004***
Artist's characteristics		
Germany	-0.2545	-0.5176
USA	0.7821*	0.3759
Russia	0.0035	-0.5119
Link's characteristics		
Share of oil paintings	6.2693	3.4184
Share of watercolors	12.3529**	4.2451
Share of drawings	-0.0392	0.5824
Share of sculptures	45.1176**	38.1053**
Share of signed	-3.6614	-2.7254
Share of 2008	24.1230**	7.0740
Share of 2009	-18.2541	-2.0767
Share of 2010	25.3134	25.3024

Share of London	-3.8261	-0.3059
Share of New York	-3.6135	-1.9739
Germany	1.6356	1.2606
USA	0.9896$^{\bullet}$	0.3583
Russia	-0.0174	-0.5003
*** - p-value < 0.001, ** - p-value < 0.01, * - p-value < 0.05, $^{\bullet}$ - p-value < 0.1		

It can be observed from Table 7, that presence of maximal estimated price causes the insignificance of some of the coefficients, significant in the sample of sold lots. For example, for both models, the type of the work is no longer relevant (with the exception of drawings in the Hausman-Taylor model). The maximal estimated price is, as expected, highly significant.

The endogenous effect, in which I am mostly interested, is present only in Hausman-Taylor model analysis. The magnitude is even bigger than in the sample of the sold lots, suggesting that the average prices of friends' work might be even more relevant for the market responses although the two models are different, and the direct comparison of the coefficient not totally correct. I also run the regressions without maximal estimated price, which repeats the model from the previous subsection completely. The results are reported in Table A.3 in Appendix. This model is a worse fit than the one above, and the endogenous effects are insignificant.

The analysis of the sample of all lots auctioned after 2003 does not detect the endogenous effect at all, whereas the other results are quite similar to the full sample (see Table A.2 in Appendix).

4.3 Full sample, Maximal and Minimal Estimated Prices

I continue the analysis of the full sample of the lots with the new outcome variable: estimated by auctioneer price of the lot. The obtained endogenous effect is opposite

from the one obtained for the final market price of sold lots.

Table 8: Results for the full sample, max and min EP

	HT, Max	IV, Max	HT, Min
Constant		18.5371***	
Av.log price of friends' works	**-1.0643*** **	**-0.6299*** **	**-1.0925*** **
Artists' dummies		incl.	
Work's characteristics			
Oil painting	2.1836***	2.2183***	2.1838***
Watercolor	0.7829***	0.7663***	0.7708***
Drawings	0.2199***	0.2258***	0.2227***
Sculpture	0.4816***	0.4512***	0.4826***
Signed	0.1162***	0.1123***	0.1118**
Sale's characteristics			
2008	0.4195***	0.3920***	0.4204***
2009	0.5097***	0.5069*	0.5125***
2010	0.6793***	0.6968***	0.6680***
London	0.5233***	0.4869***	0.5203***
New York	0.7845***	0.7376***	0.7716***
Artist's characteristics			
Germany	1.0920***	0.7959***	1.0947***
USA	-0.1613	0.0797	-0.1674
Russia	-0.3871*	-0.7442***	-0.3933*
Link's characteristics			
Share of oil paintings	-1.5643	-5.4842***	-1.6907
Share of watercolors	-9.6956***	3.8806*	-9.9808***
Share of drawings	5.1483***	1.0577•	5.3086***

Share of sculptures	-12.6471*	-4.2252	-13.9513*
Share of signed	2.3945	2.1634$^{\bullet}$	2.5370$^{\bullet}$
Share of 2008	-11.8377***	-17.6327***	-12.7042***
Share of 2009	35.3523***	14.6875**	35.4269***
Share of 2010	-32.9338***	-50.5332***	-33.0736***
Share of London	-2.9070**	-0.3744	-3.1158**
Share of New York	0.8093	1.9496	0.5636
Germany	-1.1076*	-0.9735***	-1.1208**
USA	0.0061	0.7295***	-0.0076
Russia	-1.1539***	-0.5717*	-1.1208***

*** - p-value < 0.001, ** - p-value < 0.01, * - p-value < 0.05, $^{\bullet}$ - p-value < 0.1

Results, presented in Table 8, suggest, that the higher average price is expected by the auctioneer for the artists' connections, the lower the expected price of artist's own work. This is opposite effect in comparison to what I observed for the final price of sold lots. This possibly reveals two different trends. On one hand, the market treats works of connected artists as substitutes. Once the auction house expects the high demand, and hence, high price for the works of artist's connections, it logically expects lower demand for the artist's own works. However, conditional on the sale being successful the prices of connected artists are likely to move in one direction. The increased interest in one artist leads to raising interest towards artist's connections, setting higher prices for all of them.

The other coefficient exhibit rather similar behavior as in Section 4.1. The most noticeable difference is in the estimation of the share of 2008, 2009 and 2010 in the friends' works. The effects are close to the ones from the IV estimation and are similar to the IV estimates of the sample of sold lots.

General observations about other determinants

- All of the models are able to capture the differences in the prices for different media. The types of work dummies are only insignificant in the full sample model, which includes the maximum estimated by auction house price. In this case, the effect of differences in the medium is captured by the effect of estimated price.

- The price of sold lots and the expected prices are estimated to be higher in 2008 crisis year, and two years after it when art market still did not recover from the crisis. 2009 and 2010 also have the positive effect on the price of the full sample (with 0 prices for unsold), reflecting the caution behavior of the sellers in these years. The total amount of sales went down in these two years, but the share of sold lots are higher than in the other years. It means that the lots auctioned in these two years are less risky, the lots with less uncertainty about their quality or value, hence "better" works were auctioned in these difficult for the market years. The dummy for 2008 for the full sample with unsold lots exhibits opposite behavior to the one in the sold lot sample. The share of sold lots in 2008 is very low due to the crisis, therefore, the amount of zero-priced works is higher in 2008, resulting in the negative highly significant coefficient.

- Sotheby's London and New York are the main auction locations and attract more buyers, hence, the more valuable lots are likely to be auctioned there. The price of sold lots is, therefore, likely to be higher for sales on one of the two locations. Once I am analysing the sample with unsold lots and including the maximal expected price, that accounts for a lot of lots characteristics, the prices in New York are likely to be lower. It reflects the higher probability of having unsold lots, once the volume of sales is bigger than at the other locations.

- Russian art is very popular in the recent decades[7] with every auction house having

[7]See, for example, the report on London Russian Weeks Auction sales

their own Russian Art Auction couple of times per year, and "works by Russian Avant-Garde are among the most sought-after on the international market" (Hewitt, 2014). The result of my analysis suggests that the prices of the Russian artists are on average lower, and being connected to more Russian artists lower the price as well. So the high demand for Russian art does not result in higher prices in comparison to the other nationalities. It is reasonable to assume that the affordability and availability of Russian abstract art is one of the determinants of its high demand.

5 Conclusion

This paper adopts the peer effect logic to analyse the price formation on the art market. I explore the auction results for abstract art from Sotheby's auction house for the period of 2000-first half of 2015 and the connections between the abstract artists as reported for the MOMA exhibition "Inventing abstraction". The connections between the artists can be an important determinant of the artists' style and quality of works, as well as of the resulting price of the works. It can be caused by collaborations, joint exhibitions or the particular reputation of one of the artist's connections.

I am proposing the model, combining Hausman and Taylor (1981) approach for the panel data with the Manski(1993) peer effect model and Bramoulle et al. (2009) instruments. I am also using the alternative model, that uses artists' dummies instead of the panel structure.

I am analysing both the sample of only sold lots and the full sample setting the price of unsold lots to zero. Both settings exhibit the positive peer effect of connections' works average prices, with more prominent effect in the sold lots sample. The market is, therefore, rather responsive to the artist's connections performance and reputations and the buyers are willing to pay more if the artist is connected to the "better" artist.

The auctioneers behaviour towards price formation is, however, likely to be different.

The more valuable the average works of the connected artists are, the smaller is the expected minimal and maximal prices set by the auction house before the sales begin. The auction house probably views the connected artists as substitutes. Moreover, the more "valuable" peer group of particular artist suggests that the best artists among the group and the artist him/herself are probably among the peer group and not the artist. Hence, this artist's work are valued lower by the specialists.

The data used in the analysis have several limitations described in Section 3, which can distort some of the results. However, the paper shows clear evidence of the importance of connections in the price formation and market outcomes at the art market.

Appendix. Additional figures

Table A.1: Artists in the sample

Name	Years	Main mode	Country born/active	Group belonging
Josef Albers	1888-1976	Paintings	Germany/ USA	-
Guillaume Apollinaire (not incl.)	1880-1918	Art critic	Poland, Italy/ France	-
Hans Arp	1886-1966	Sculpture	Germany, France	Der Blaue Reiter
Lawrence Atkinson	1873-1931	Paintings (graphical)	England	-
Giacomo Balla	1871-1958	Paintings	Italy	-
Vanessa Bell	1879-1961	Paintings	England	Bloomsbury group
Henryk Berlewi	1894-1967	Paintings	Poland/ Germany, France	-
Umberto Boccioni	1882-1916	Paintings (Sculpture)	Italy	-
David Bomberg	1890-1957	Paintings	England	Whitechapel Boys
Anton Giulio Bragaglia	1890-1960	Photography	Italy	-
Constantin Brancusi	1876-1957	Sculpture	Romania/ France	-
Patrick Henry Bruce	1881-1936	Paintings	USA	-
Francesco Cangiullo	1884-1977	Paintings	Italy	-
Carlo Carra	1881-1966	Paintings	Italy	-
Blaise Cendrars (not incl.)	1887-1961	Writer	Switzerland/ France	-
Alvin Langdon Coburn	1882-1966	Photographt	USA	Linked Ring
Claude Debussy (not incl.)	1862-1918	Composer	France	-
Robert Delaunay	1885-1941	Painings	France/ Spain, France	Der Blaue Reiter, Puteaux Group
Sonia Delaunay-Terk	1885-1979	Paintings	Ukraine/ Spain, France	-
Fortunato Depero	1892-1960	Paintings (Sculpture)	Italy/ Italy, USA	-

Theo van Doesburg	1883-1931	Paintings	The Netherlands	De Stijl
Arthur Dove	1880-1946	Paintings	USA	-
Marcel Duchamp	1887-1968	Paintings (Sculpture)	France/ France, USA	Societe Anonyme, Puteaux Group
Suzanne Duchamp	1889-1963	Paintings	France	-
Viking Eggeling	1880-1925	Various media	Sweden/ Germany	Das Neue Leben, Novembergruppe
Kseniia Ender	1894-1955	Paintings	Russia	-
Henri Gaudier-Brzeska	1891-1915	Sculpture	France/ France, England	-
Augusto Giacometti	1877-1947	Paintings	Switzerland/ Switzerland, Italy	-
Natalia Goncharova	1881-1962	Paintings	Russia/ Russia, France	Puteaux Group, Donkey's Tail
Duncan Grant	1885-1978	Paintings	England	Bloomsbury Group
Marsden Hartley	1877-1943	Paintings	USA/ USA, Germany	-
Vilmos Huszar	1884-1960	Paintings	Hungary/ The Netherlands	De Stijl
Vasily Kandinsky	1866-1944	Paintings	Russia/ Russia, Germany	Der Blaue Reiter
Paul Klee	1879-1940	Paintings	Switzerland/ Germany, Switzerland	Der Blaue Reiter
Ivan Kliun	1873-1943	Sculpture	Russia	Union of Youth, Supremus
Gustav Klutsis	1895-1938	Photography	Latvia/ Latvia, Russia	-
Katarzyna Kobro	1898-1951	Sculpture	Russia/ Russia, Poland	-

Aleksei Kruchenykh (not incl.)	1886-1968	Poet	Russia	-
Frantisek Kupka	1871-1957	Paintings (Graphics)	Czech Republic/ France	Puteaux Group
Rudolph von Laban (not incl.)	1879-1958	Dancer	Hungary/ Germany, Switzerland	-
Mikhail Larionov	1881-1964	Paintings	Russia/ Russia, France	Jack of Diamonds, Donkey's Tail
Fernand Leger	1881-1955	Paintings	France	Puteaux Group
Wyndham Lewis	1882-1957	Paintings	Canada/ England	-
El Lissitzky	1890-1941	Graphics (Photography)	Russia/ Russia, Germany	UNOVIS
Stanton Macdonald-Wright	1890-1973	Paintings	USA	Synchromism
August Macke	1887-1914	Paintings	Germany	Der Blaue Reiter
Kazimir Malevich	1878-1935	Paintings	Russia	Union of Youth, Supremus, UNOVIS, Donkey's Tail
Franz Marc	1880-1916	Paintings (Printmaker)	Germany	Der Blaue Reiter
Filippo Tommaso Marinetti (not incl.)	1876-1944	Poet	Italy/ Italy, France	-
Mikhail Matiushin	1861-1934	Paintings	Russia	Union of Youth
Laszlo Moholy-Nagy	1895-1946	Photography (various media)	Hungary/ Germany, England, USA	-
Piet Mondrian	1972-1944	Paintings	The Netherlands/ France, The Netherlands	De Stijl
Vaslav Nijinsky (not incl.)	1889-1950	Dancer	Russia/ France, Russia	-
Georgia O'Keeffe	1887-1986	Paintings	USA	291 Gallery
Emilio Pettoruti	1892-1971	Paintings (Drawings)	Argentina/ Italy, Argentina	-

Francis Picabia	1879-1953	Paintings	France/ France, USA, Spain	Puteaux Group
Pablo Picasso	1881-1973	Paintings (Sculpture)	Spain/ France, Spain	-
Liubov Popova	1889-1924	Paintings	Russia/ Russia, France	Knave of Diamonds, Supremus
Man Ray	1890-1976	Photography (Various media)	USA/ USA, France	-
Hans Richter	1888-1976	Paintings (Filmmaker)	Germany/ Germany, Switzerland, USA	Artistes Radicaux
Aleksandr Rodchenko	1891-1956	Photography (Sculpture)	Russia	October Circle
Morgan Russel	1886-1953	Paintings	USA/ USA, France	Synchromism
Luigi Russolo	1885-1947	Paintings (Composer)	Italy/ Italy, Argentina	-
Helen Saunders	1885-1963	Paintings	England	-
Christian Schad	1894-1982	Paintings	Germany/ Germany, Switzerland, Italy	-
Morton Livingston Schamberg	1881-1918	Paintings (Photography)	USA	Societe Anonyme
Arnold Schoenberg (not incl.)	1874-1951	Composer	Austria/ Germany	Der Blaue Reiter
Kurt Schwitters	1887-1948	Various media	Germany	-
Gino Severini	1883-1966	Paintings	Italy/ Italy, France	-
Ardengo Soffici	1879-1964	Paintings (Writer)	Italy/ Italy, France	-
Joseph Stella	1877-1946	Paintings	Italy/ USA, France, Italy	-
Alfred Stieglitz	1864-1946	Photography	USA	291 Gallery
Paul Strand	1890-1976	Photography	USA	291 Gallery
Wladyslaw Strzeminski	1893-1953	Paintings	Poland/ Russia	Blok
Leopold Survage	1879-1968	Paintings	Russia/ France	-
Waclaw Szpakowski	1883-1973	Graphics	Poland	-
Sophie Taeuber-Arp	1889-1943	Paintings (Graphics)	Switzerland	Cercle el Carre
Vladimir Tatlin	1885-1953	Paintings (Architecture)	Russia	Union of Youth

Tristan Tzara (not incl.)	1896-1963	Poet	Romania/ Romania, Switzerland, France	-
Georges Vantongerloo	1886-1965	Sculpture	Belgium/ The Netherlands, France	De Stijl
Edgar Varese (not incl.)	1883-1965	Composer	France/ Germany, USA	-
Max Weber	1881-1961	Paintings	Russia/ USA	-
Mary Wigman (not incl.)	1886-1973	Dancer	Germany/ Germany, Switzerland	-

Table A.2: Results for full sample, after 2003

	HT	IV
Constant		-5.606
Log Max EP	0.6164***	0.6265***
Av.log price of friends' works	**0.2332**	**0.3782**
Artists' dummies		incl.
Work's characteristics		
Oil painting	0.1828	0.1103
Watercolor	0.1940	0.0753
Drawings	-0.1988***	-0.1968***
Sculpture	0.2632	0.2958
Signed	0.5584***	0.5464***
Sale's characteristics		
2008	-1.5539***	-1.486***
2009	0.2594	0.3253
2010	1.7851***	1.804***
London	0.0750	0.0666
New York	-0.6135***	-0.5949***
Artist's characteristics		
Germany	-0.7793	-0.7548
USA	0.6151	0.2056
Russia	0.0853	-0.0111
Link's characteristics		
Share of oil paintings	6.7206	6.465
Share of watercolors	5.9433	2.887
Share of drawings	4.0074	3.352$^{\bullet}$
Share of sculptures	22.5245	42.94*
Share of signed	-0.8956	-3.304
Share of 2008	1.5815	9.164
Share of 2009	-4.6728	1.596
Share of 2010	30.2939	10.38
Share of London	-4.0689	-3.300
Share of New York	-6.1573	-4.396$^{\bullet}$
Germany	2.6296$^{\bullet}$	2.522**
USA	-0.6291	-0.1124
Russia	-0.8737	-1.067

*** - p-value < 0.001, ** - p-value < 0.01, * - p-value < 0.05, $^{\bullet}$ - p-value < 0.1

Table A.3: Results for full sample, first model

	HT	IV
Constant		5.0217
Av.log price of friends' works	**0.5152**	**0.0674**

Artists' dummies		incl.
	Work's characteristics	
Oil painting	1.5214***	1.5643***
Watercolor	0.5148*	0.5036*
Drawings	0.0044	0.0127
Sculpture	0.6098*	0.5586*
Signed	0.6869***	0.6794***
	Sale's characteristics	
2008	-1.2225***	-1.1155***
2009	0.7140***	0.7433***
2010	2.2849***	2.3561***
London	0.3230**	0.2696*
New York	-0.0103	-0.0466
	Artist's characteristics	
Germany	0.4028	0.0228
USA	0.6813*	0.3854
Russia	-0.2602	-1.0098*
	Link's characteristics	
Share of oil paintings	5.4281	0.1631
Share of watercolors	5.0402	6.0087
Share of drawings	3.3378	1.2951
Share of sculptures	37.9046*	35.5186*
Share of signed	-2.3242	-1.6292
Share of 2008	16.7121$^{\bullet}$	-3.7773
Share of 2009	0.8907	4.1055
Share of 2010	3.4210	-6.4842
Share of London	-5.3984*	-0.2770
Share of New York	-2.9385	-0.5461
Germany	0.9276	0.5358
USA	1.0146$^{\bullet}$	0.8755$^{\bullet}$
Russia	-0.7959	-0.8468

*** - p-value < 0.001, ** - p-value < 0.01, * - p-value < 0.05, $^{\bullet}$ - p-value < 0.1