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A Model for Pricing the Italian Contemporary Art Paintings at Auction

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Abstract

This paper aims to model the auction prices of Italian contemporary art paintings. The contribution to the existing literature is twofold concerning both the methodological and the conceptual aspects. From the former point of view, we use the two-stages Heckit model which allows us to take into account the sample selection bias deriving from the "buying" risk, that affects transactions at auction. From the latter point of view, we have found that some sale characteristics such as auction house prestige and year of sale, are more important than the physical aspects of the paintings. Moreover, some artistic characteristics, the artist's name and their living status are also relevant.

An estimation using pre-sale evaluation by experts has also been tried: this explanatory variable seems to be the main driver regarding both the probability of having an unsold painting and the auction price levels reached by sold works. Nevertheless, the hypothesis of its sufficiency is rejected and some problems related to the economic interpretation of the results arise.

The whole analysis is carried out after creating a new dataset of 2817 transactions which took place at the most important auction houses between 1990 and 2006.

JEL Class.: C34, D44, Z11
Keywords: painting prices, auctions, Heckit model, selection bias, statistical sufficiency

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A Model for Pricing the Italian Contemporary Art Paintings at Auction*

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1 Introduction

The prices of paintings depend upon a set of variables, concerning the characteristics of the paintings themselves, but also other aspects more difficult to be measured, such as the artist's popularity or the auction house's prestige. As a consequence, they may dramatically change over time increasing the uncertainty in the market. Nowadays, several questions about the level of art prices are still open: in particular, literature has not clearly defined what are the main drivers of their dynamics and what are the conditions for a more liquid and riskless investment in artworks.

From the theoretical point of view, there are two main theories regarding the price determination: on one hand, Baumol (1986) claims that there may exist no equilibrium level for art prices, so they can float more or less aimlessly with unpredictable oscillations emphasized by the activities of investors/speculators; on the other hand, Frey and Pommerehne (1991) assume that a "natural price" does not exist for paintings, neverthless market forces related to demand and supply determine prices for artworks, as for any other economic good.

From the empirical point of view, the pricing of paintings is generally discussed within the framework of market price indexes, with the aim of evaluating the rate of return of an investment upon such assets. In this context, the hedonic regression (from Anderson, 1974 onwards) seems to be a good methodology to select the variables which can be useful to model the evolution of artwork prices.

The key-objective of this paper is to carry out an empirical analysis about

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the price determinants of Italian contemporary art paintings at auction. The analysis is two-fold because it allows us to jointly model how some explanatory variables contribute to the probability of having an unsold item and to the price levels of sold works.

In doing so, a preliminary sample selection is obviously required. We consider a sample of 2817 painting transactions from the 21 Italian contemporary artists who showed the biggest turnover at auction during the period 1998-2002, according to Sacco, Santagata and Trimarchi (2005). Starting from the available information about this sample of transactions, we made a new dataset in which all the variables are grouped into four categories, being the usual painting-specific attributes: they are the physical qualities of the work, the characteristics of the artist, the artistic and the sale characteristics of the paintings.

The reminder of this paper is organized as follows: in section 2 we discuss the theoretical aspects of pricing in the market of paintings, while in section 3 we introduce the problems related to the sample selection and the choice of the relevant variables. The whole empirical analysis is carried out in section 4 and section 5 concludes. Finally, the Appendix includes the complete list of all available variables.

2 Literature

The work of Frey and Pommerehne (1991) represents one of the first empirical studies regarding the determinants of art pricing; this article selects a list of endogenous and exogenous variables, in order to estimate the artistic quality of a painting and its impact upon prices. Other studies focussed upon these aspects followed, increasing the number of variables included in the price model and widening the perspective of the art price analysis within the context of market price indexes. In this area, the most important indexes are those based on:

- experts' judgement, such as the Sotheby's Art Index;
- the average painting methodology (Stein, 1977), with its refinement of the representative painting (Candela and Scorcu, 1997);
- repeat sales regression (Goetzmann, 1993; Pesando and Shum, 1999; Locatelli-Biey and Zanola, 1999; Mei and Moses, 2002);
- hedonic regression (from Anderson, 1974 onwards)[1];

[1]See also Frey and Pommerehne (1991), Buelens and Ginsburg (1993), Chanel (1995),

- hybrid approach (see Locatelli-Biey and Zanola, 2005).

Among the methodologies developed to evaluate the rate of return of an artwork investment, the hedonic regression is able to identify the most relevant explanatory variables in determining the art prices. The essential approach is to gather price data on art sales through time (generally auction sales) and to regress the price of each work on some available characteristics of the painting such as, for example, the identity of the artist, the size of the painting, the medium or the support. The coefficients related to the different characteristics of the work could be interpreted as the "shadow-prices" of each attribute, thus the results of the hedonic regression permit the gauging of the influence of the separate factors upon the paintings' auction prices.

Regarding the perspective of price formation, the previous studies present the following key-issues:

a) the variables related to the physical attributes are generally prevalent compared to other factors connected with the artistic relevance of the work and its promotion. Only for some authors the explanatory variables which capture the popularity and the artistic recognition of the artists and their work are relevant[2]. On the contrary, a well-run activity of artistic and commercial promotion is likely to strongly affect the market price of paintings, expecially in the area of contemporary art;

b) only the sold works are considered, even if the problem of "unsold" or "bought-in" paintings is relevant and it could affect the future market valuation of the painting (see Anderson, 1974). In each auction trading the seller fixes a reservation price that corresponds to the minumum price at which the item can be sold; when the highest bid does not reach the reserve price, the painting goes unsold or bought-in;

c) sometimes these contributions deal with paintings belonging to different artistic movements. Even though the basic determinants of prices are common for several artistic currents, there is a lack of homogeneity because each segment of the market can have its own dynamics.

Ginsburgh and Jeanfils (1995), Chanel, Gérard-Varet and Ginsburgh (1996), Agnello and Pierce (1996), Czujack (1997), Renneboog and Van Houtte (2002), Agnello (2002), Hodgson and Vorkink (2004), Higgs and Worthington (2005), Figini and Onofri (2005) and Worthington and Higgs (2006).

[2]For example, only Czujack (1997), Wieand, Donaldson and Quintero (1998) and Figini and Onofri (2005) take into consideration the previous ownership of the painting and its presence in exhibitions; Wieand, Donaldson and Quintero (1998) and Figini and Onofri (2005) also consider the citations of the work in the artistic literature.

3 The sample selection

The analysis of the price dynamics of paintings sold at auction has to be based upon the choice of an appropriate sample. In this article, all the available information is taken from "Artindex Plus", a detailed database which contains the catalogue's information about several artworks[3]: more precisely, it provides the picture of the painting plus different pieces of information about the artist and the artwork itself (see section 3.1 for details).

Our sample choice substantially depends upon the reaching of a sort of homogeneity between variables: given that the market of paintings is composed of unique goods, we focus the attention upon Italian contemporary art because we need to deal with goods as comparable as possible[4].

Since Italian contemporary art itself is not completely homogeneous[5], we limited our analysis to the 21 Italian contemporary artists who showed the biggest turnover at the most important international auctions during the period 1998-2002, according to Sacco, Santagata and Trimarchi (2005)[6]. The reason for this selection is that the paintings are considered as investment goods for which the main characteristics depend upon the market dynamics; the aestethic component is not supposed to be relevant here. The homogeneity in our sample is also preserved by the exclusion of prints and drawnings because these items have their own specific price dynamics, as claimed by Holub, Hutter and Tappeiner (1993), and are often traded in separate ses-

[3]Artindex Plus is provided by Gabrius S.p.A. operating in Milan and belonging to the Munus Culture Holding (AMB network); nowadays it contains more than 700000 items (paintings, sculptures, drawnings, prints) produced from 1300 until today and auctioned from 1980 onwards. Artindex Plus information comes from more than 13000 catalogues. For more details see *http://www.munusartinvest.com.*

[4]The market of paintings is usually divided in four branches which have their own dynamics and characteristics: Old Master, XIX Century, Modern Art and Contemporary Art. Taking care for the homogeneity, our choice of the latter segment is due to the easy ability of obtaining and updating sample data.

[5]In practice, there are differences among "emerging" and "historical" contemporary art painters: first, each category has its own place to expose and sell the artworks and second, for emerging contemporary art painters catalogues have a promotional aim, while for the historical contemporary art painters catalogues guarantee authenticity.

[6]Sacco, Santagata and Trimarchi (2005) define the "turnover" as the number of sold works multiplied by their mean price.

Moreover, they conventionally define as the Italian contemporary artists those Italian painters who carried out their activity after 60's. This selection criterium is not strictly applied, since some Italian painters, still working after 1960's, but historically placed with the best artists of Futurism or other artistic currents preceding the 1960's, are not included in their sample (for example, Carlo Carrà). So, in the analysis of Sacco, Santagata and Trimarchi (2005), the Italian contemporary art conventionally starts with the contributions of Fontana (1899-1968), Burri (1915-1995), Marini (1901-1980) and Manzoni (1933-1963).

sions at auction.

Finally, we restrict the period of observation to the years which go from 1990 to 2006, since the Artindex Plus data regarding auction sales before 1990 are very poor and incomplete.

Following this sample selection, we work with a dataset of 2817 painting transactions placed at the most important auction houses between 1990 and 2006. The complete list about the authors and the auction houses are provided in Tables 9 and 12 in the Appendix.

Table 1 reports the geographical distribution of painting transactions, in order to derive the size of the Italian Contemporary Art in the national and the foreign markets.

The Italian Contemporary Art market does not seem to be merely national: the percentage of paintings sold abroad over time is always greater than the percentage of artworks traded in Italy, even if the market share of Milan is close to the size of London market. Therefore, the competition ground for Italian Contemporary Art paintings seems to be global.

Table 1: Italian contemporary art paintings traded at auction inside and ouside Italy

	Foreign auctions				Italian auctions			
	London	NY	Other	Total	Milan	Rome	Other	Total
1990	37.19	10.33	2.89	50.41	34.71	14.88	0.00	49.59
1991	28.00	23.00	9.00	60.00	34.00	6.00	0.00	40.00
1992	26.62	28.78	68.63	64.03	28.06	7.91	0.00	35.97
1993	46.79	12.84	8.26	67.89	29.36	2.75	0.00	32.11
1994	32.33	14.29	6.77	53.38	39.85	6.77	0.00	46.62
1995	45.93	9.63	4.44	60.00	34.81	5.19	0.00	40.00
1996	43.92	12.16	2.70	58.78	37.84	3.38	0.00	41.22
1997	54.33	8.66	4.72	67.72	30.71	1.57	0.00	32.28
1998	42.24	15.52	2.59	60.34	36.21	3.45	0.00	39.66
1999	42.11	13.68	4.21	60.00	37.89	2.11	0.00	40.00
2000	39.24	14.56	2.53	56.33	35.44	8.23	0.00	43.67
2001	45.60	14.84	3.30	63.74	31.32	1.10	3.85	36.26
2002	38.81	10.45	6.97	56.22	34.83	8.96	0.00	43.78
2003	36.41	11.17	9.71	57.28	40.29	2.43	0.00	42.72
2004	37.97	14.97	14.44	67.38	30.48	2.14	0.00	32.62
2005	36.64	7.76	11.64	56.03	43.97	0.00	0.00	43.97
2006	38.21	7.55	10.85	56.60	33.49	5.19	4.72	43.40
Total	**39.37**	**12.89**	**6.89**	**59.14**	**35.29**	**4.97**	**0.60**	**40.86**

Source: Artindex Plus - Gabrius S.p.A.
All values are expressed as percentages and they refer to sold and unsold paintings.

A problem encountered in studying art prices stems from the fact that

the auction data samples could suffer from some problems of selection bias, as already underlined by Wieand, Donaldson and Quintero (1998). It is well known that the art market is divided into "primary", "secondary" and "auction" market: in the former the artist personally sells her works to buyers, while in the second the galleries and the art dealers trade paintings with private or istitutional collectors. Auction represents the remaining solution, therefore it can not take into account all types of paintings[7]. Neverthless, in this case public information exists and this overcomes most of the typical problems due to the incomplete and asymmetric information availability of the art market. Moreover, we suppose that auction prices affect the art market because collectors and professional art dealers take these price as guidelines, following the approach of Frey and Pommerehne (1989). Finally, we also consider auction prices as adequate approximations of true equilibrium prices, as pointed out by Candela and Scorcu (1997).

With this sample selection, we try to give an empirical contribution for a sector that literature has often neglected[8].

3.1 The data

For each item Artindex Plus provides the following information:

a) a picture of the painting,

b) personal details about the artist,

c) physical characteristics of the painting (date of execution, width and height, support, medium),

d) artistic characteristics of the painting (list of previous owners, signature, date, title, expertise, literature citations, list of exibitions),

[7]For example, several paintings made by young/unknown artists are generally managed by the artists themselves or by the galleries; paintings with "extreme" prices, generally bought by museums, exit the market and are not traded at auction anymore.

[8]Buelens and Ginsburg (1993) evaluated price indexes for English, German, Italian and French artworks without focussing their attention to a specific period, Agnello and Pierce (1996) use the auction prices of the main American authors to create a price index, while Mok, Ko, Woo and Kwok (1993) carry out the same analysis for Chinese authors. The contributions of Renneboog and Van Houtte (2002) and Hodgson and Vorkink (2004) consider the art market of Belgium and Canada respectively. Only the work of Candela and Scorcu (1997) uses data about the Italian market of Modern and Contemporary oil paintings; however, in this contribution foreign painters are also considered, because the dataset includes some transactions of Modern and Contemporary Art paintings auctioned in Italy, by "Casa d'aste Finarte" in Rome and Milan.

e) sale characteristics of the painting (lot number, auction house, city, month and year of transaction),

f) economic characteristics of the paintings (hammer prices, hammer prices plus transaction fees, pre-sale evaluation by experts who provide the estimation of a range of prices).

Tables in the Appendix report the descriptions of the variables used in our work.

3.2 The variables

3.2.1 Dependent variables

Given that we aim to model the auction price levels taking into account the problem of unsold paintings, our dependent variable is given by the auction price of each painting. In our dataset we have both the hammer price and the total purchase price: the latter differs from the former because it includes the auction house's transaction fees. All the prices related to unsold paintings at auction are not observable, hence they are set as zero.

Both types of prices are originally recorded in local currency, hence they are all converted to US Dollars to make them comparable, obtaining series p_i and P_i respectively[9]. Finally, we consider their logarithmic transformation, indicated with y_i and Y_i.

Descriptive statistics of p_i, P_i, y_i and Y_i are reported in Table 2, while Figure 1 plots their frequency distribution. They refer only to sold works with a total purchase price greater than zero (missing values = 807).

3.2.2 Explanatory variables

The main evidence related to the variables identification concerns the qualitative nature of most of the available data; for this reason several variables are dummies (see the Appendix for details).

The explanatory variables for the price of Italian contemporary art paintings are organized into four categories; the list of potential price determinants and their codes are reported in the Appendix.

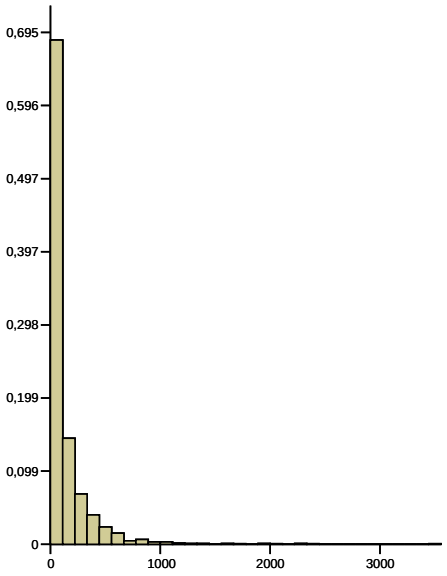
A. Characteristics of the artist: the explanatory variables belonging to this category are related to the personal characteristics of the artist who painted the work. Specifically, we include in this area the following information.

[9]We use a daily exchange rate, desumed from *http://fxtop.com/it/historates.php3.*

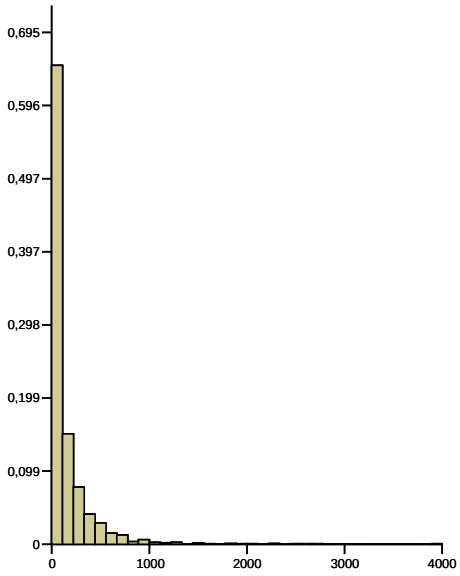
Figure 1: Price of paintings: frequency plot (sold paintings)

Levels

(a) Variable p_i

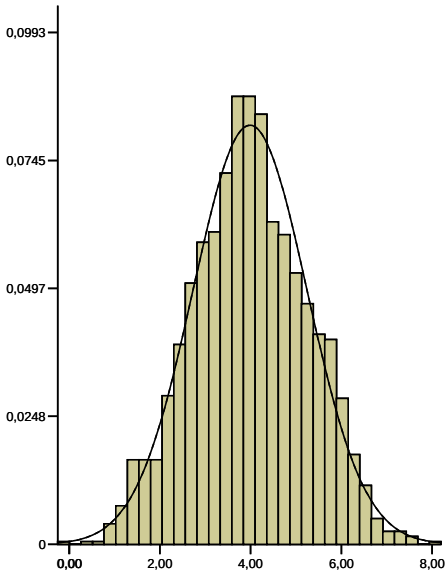


(b) Variable P_i



Logarithms

(c) Variable y_i



(d) Variable Y_i

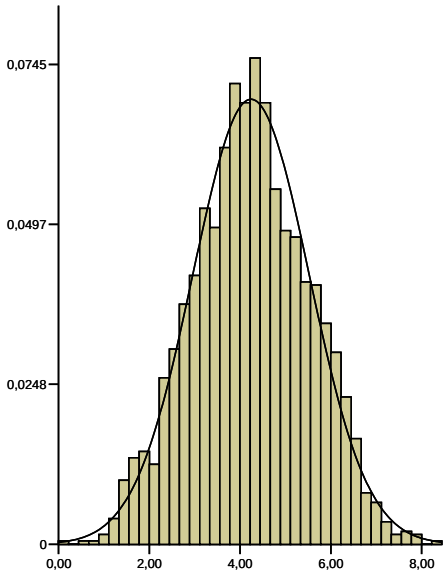


Table 2: Price of paintings: descriptive statistics (sold paintings)

	p_i	P_i	y_i	Y_i
Mean	134.220	153.330	4.094	4.241
Median	58.960	68.813	4.077	4.231
Minimum	0.934	1.051	-0.068	0.050
Maximum	3534.800	3973.800	8.170	8.288
Standard Deviation	226.620	255.540	1.291	1.281
Variation Coefficient	1.688	1.667	0.315	0.302
Skewness	5.497	5.453	0.010	0.004
Exc. Kurtosis	49.152	48.540	-0.284	-0.287
Jarque-Bera Test	10035.485	9760.877	6.976	7.083
p-value	0.000	0.000	0.036	0.028

Source: Artindex Plus - Gabrius S.p.A.
Prices are expressed in thousands of US Dollars.

1) Name of the artist
According to Grampp (1989), the reputation of the painter and the title of the painting are essential attributes, since they provide information about the painting itself, such as style and subject (see also Worthington and Higgs, 2006). We use 21 different dummy variables, one for each artist in the sample, as shown in Table 9.

2) Living status
This variable takes the form of a dummy with a value of one if the painter is deceased at the time of the sale and zero otherwise. All other things being equal, the price of artworks are often supposed to increase once an artist has died, as pointed out by Higgs and Worthington (2005).

3) Year of birth
This variable is simply given by the artist's year of birth.

B. Physical characteristics: this type of variables take into consideration different aspects related to the execution of the artwork.

4) Medium
This variable allows us to control the assumption of a superior market value as a consequence of the media durability and particulars[10]. Table 10 contains the complete list of dummy variables

[10]Generally, oil paintings are supposed to be more expensive than other media. See, among others, Czujack (1997), Renneboog and Van Houtte (2002), Hodgson and Vorkink (2004), Higgs and Worthington (2005).

belonging to this group; this also allows us to model all the cases in which different media are jointly used.

5) Support
In our database, we have 10 different types of support upon which the artwork is painted (see Table 10). The related dummy variables have the value of one when the specified support is used, alone or jointly with another, and zero otherwise.

6) Size
The size is given by the dimensions of the painting, used to calculate the surface (expressed in m^2) and the squared surface as in Czujack (1997), Renneboog and Van Houtte (2002), Higgs and Worthington (2005) and recently in Zanola (2007). Following Czujack (1997), who describes the price of painting as a concave function of dimensions, we expect a positive relationship between the price of the painting and its area and negative sign for the coefficient of the squared surface. This is coherent with two empirical pieces of evidence: first, large paintings are more expensive than smaller ones and second, too large paintings are difficult to sell to all but a museum.

C. Artistic characteristics: the variables of this category can be considered as proxies of the prestige and the popularity of the artwork in the art world.

7) Authentication by the artist
The presence of an authentication by the artist is useful to reduce the probability of buying a fake; the informative value of this indication is high, especially when many fake works of an artist are easily traded[11]. Similarly to previous qualitative characteristics of the painting, we use a dummy variable, with a value of one if the artist has certified the authenticity of the work and zero otherwise.

8) Publication in catalogues or monographies
The section "expertise" of Artindex Plus allows one to know whether the artwork has been published in catalogues/monographies. This is of some interest for the potential buyer, in order to establish the authenticity of the work[12]. A dummy is the natural

[11]For example, Alighiero Boetti's works have no market value if they are not accompanied by an authentication, since the number of fakes is high for this artist.

[12]For example, the Lucio Fontana's Foundation has recently published an exclusive catalogue, reporting an updated list of works painted by the artist; if a painting is not included in this list, the risk of non-authenticity is high.

counterpart of this qualitative information; it has the value of one if the painting is published in catalogues or monographies, and the value of zero if not.

9) Date
Sometimes, the catalogue does not report the execution date of the work. On the contrary, the creation date of the painting could be of interest to the buyer. Therefore we create a dummy variable, that has a value of one if the painting is dated and zero otherwise.

10) Recognition by experts
The section "expertise" of Artindex Plus also provides information about the presence of specific reports made by art experts that is one of the most official ways to certify the authenticity of an artwork. In order to evaluate whether a recognised painting gains a market premium or not, we introduce a dummy variable which take this into account.

11) Literature
As in Figini and Onofri (2005), we try to model the relationship between the marketability of the painting and the citations in the artistic literature; for this purpose we introduce a dummy variable, equal to one if the painting is cited, and zero otherwise.

12) Signature
A buyer could derive some benefits from a signed work, in terms of prestige services or authenticity of the work[13]. The existence of the signature could have an influence upon the price; in order to control this relationship, we introduce a dummy variable with value one if the painting is signed and zero otherwise.

13) Title
Sometimes, the knowledge of the title could be considered a further piece of information by the buyer, enabling her to widen the set of available data. In order to analyse the title contribution upon the price determination of a painting, we introduce a dummy variable, equal to one if the work is titled and zero otherwise.

14) Exhibitions
In general, works that have been often exhibited are likely to reach a higher market value. Nevertheless, a painting belonging to a private collection, which has not been seen for a long time, could be

[13]Signature does not serve as an absolute guarantee against fakes, as one might think; originality is checked only by experts. Auction houses, in principle, put on sale only works whose originality has been confirmed by experts.

attractive for collectors and reach a higher price. Since the final effect of exhibitions on price does not seem to be clear, we add this variable in our model. The available data do not allow us to distinguish between different types of exhibitions (such as permanent or temporary, solo or group exhibitions), thus the variable is given by the number of exhibitions the painting have taken part in.

15) Number of previous owners
According to auction houses, the price reached for a painting is influenced by its provenance. The dataset does not allow us to classify all previous owners according to their institutional nature (for example, museum, gallery or private collector), because it provides only the names of previous owners. The number of previous owners can be useful in order to test whether a painting rarely traded in the auction market reaches a greater price than a painting that has often been put on sale (see Fiz, 1995).

D. Sale characteristics: with this set of explanatory variables we test the hypothesis that sale conditions have an effect upon the marketability and upon the final price reached by the painting at auction.

16) Auction house
Table 12 reports all the auction houses where the paintings belonging to our sample are traded. In the absence of transaction costs, the law of one price dictated that no significant price difference should exist for paintings of similar quality. However, Pesando (1993), De la Barre, Docclo and Ginsburgh (1994), Renneboog and Van Houtte (2002), Hodgson and Vorkink (2004), Higgs and Worthington (2005), among others, show that Christie's and Sotheby's systematically obtain higher hammer prices; this evidence is generally attributed to the leading role played by both institutions in this business. We use a dummy variable for each auction house.

17) Marketplace
Some auction houses have worldwide offices and, as a consequence, we account for 18 different marketplaces. Some geographical areas could be more active than others hence, we introduce a dummy variable for each city of sale, in order to estimate the influence of marketplace upon the determination of Italian contemporary art prices[14].

[14]Among others, Czujack (1997), Renneboog and Van Houtte (2002), Figini and Onofri

18) Sale date

In our model, we consider only sale year and month; specifically, we introduce a dummy variable for each year (from 1990 to 2006) and a dummy variable for each month of sale. The aim is to catch possible seasonal effects in the price formation of paintings[15].

19) Pre-sale estimates

Before an auction sale takes place, experts usually provide an estimate of the potential market value of the painting. Since this information is an indicator for the expected hammer price and for the seller's reservation price, its availability surely produces some effects upon the transaction. Since salesrooms provide pre-sale estimates as a range (M_i, maximum potential price; m_i, minimum potential price), in our model we choose the midpoint of this range (Czujack, 1997), as reported in equation

$$\mu_i = \begin{cases} \ln\left(\dfrac{m_i + M_i}{2}\right) & \text{if } m_i + M_i > 0 \\ \\ N.A. & \text{if } m_i + M_i = 0 \end{cases} \tag{1}$$

When $m_i + M_i = 0$, it means that the pre-sale estimates are on request, therefore they are not public. Obviously, for the properties of logarithm, when $m_i + M_i = 0$ it follows that μ_i is not available and the corresponding observations are dropped from the sample.

If experts set m_i and M_i taking all the available information into account, equation (1) can be thought as a sufficient statistic for the auction price: as a consequence, μ_i would be the only relevant explanatory variable. Otherwise, if it partially captures all the information, the impact of the other variables will affect the difference between auction prices and a function of pre-sales estimates. This problem will be discussed in section 4.3.

(2005) take into consideration the sale city in their hedonic regression for the price of paintings.

[15]In their empirical study, Worthington and Higgs (2006) show that the most expensive sales of Australian Contemporary and Modern paintings take place on July and August, even if auction houses work continuously throughout the year. Agnello and Pierce (1996), focussing on American Art Market, conclude that "January, the base month, results in the lowest auction prices, while December, May and August experience relatively higher prices....although July and August are low volume months".

4 The model

The aim of our proposed methodology is to model the auction prices of the Italian Contemporary Art paintings. Examining the determinants of auction prices from a speculative perspective, we have to consider the possibility of unobserved final prices; in other words, as well as the price reached by sold works, we have to take into account the "buying risk" affecting each transaction. Since in our sample various artworks go unsold, the analysis must be divided into two stages: in the first stage, a distinction between sold and unsold paintings is made, while in the second stage, prices of sold paintings are modelled.

4.1 The Heckit model

From the statistical point of view the possibility of unsold items at auction imply a problem of selection bias which can arise from censoring data. In particular, the properties of painting prices can vary taking unsold works into account, thus data can suffer from nonrandomness.

To address this problem the Heckit model (Heckman, 1979) is used; this model allows us to carry out the analysis when the dependent variable is continous but censored for values under a defined threshold. This methodology, which has been applied in different fields of research (labour economics, health economics or studies in R&D among others), was introduced to correct the selection bias occurred for nonrandomly selected samples and provides consistent estimates which eliminate the specification error for the case of censored data. Recently, Zanola (2007) used this methodology upon a sample of Picasso prints censored for repeat-sales, as well as Collins, Scorcu and Zanola (2007) upon a sample of Symbolist paintings.

Analitically, the Heckit model consists of

$$\begin{cases} s_i^* = z_i'\gamma + u_i & i = 1, 2, ..., N \\ w_i = x_i'\beta + \varepsilon_i & \Leftrightarrow \ s_i^* > 0, \end{cases} \tag{2}$$

where N is the sample size. The first equation is the "selection equation", where s_i^* is a latent variable which is positive if the auction price is greater than the reservation price. Moreover, the $1 \times K$ vector z_i' contains the individual characteristics that determine if the painting is sold or not, γ is a K-dimensional vector of unknown parameters and u_i is a random disturbance. The latent variable s_i^* is not observed, therefore we define a dichotomic variable s_i as

$$s_i = \begin{cases} 1 & \text{if } s_i^* > 0 \\ 0 & \text{otherwise.} \end{cases} \tag{3}$$

In practice, for sold paintings $s_i = 1$, while it is zero otherwise.

The second equation of the system (2) is the linear model of interest in which w_i is the dependent variable; x_i is the $1 \times M$ vector of exogenous variables, β is a M-dimensional vector of unknown parameters and ε_i is a random error term. The explanatory variables in x_i could be also included in z_i and viceversa. Moreover, we assume that the random disturbances are jointly distributed as

$$\begin{bmatrix} u_i \\ \varepsilon_i \end{bmatrix} \sim \text{i.i.d.} \left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_u^2 & \sigma_{u\varepsilon} \\ \sigma_{u\varepsilon} & \sigma_\varepsilon^2 \end{bmatrix} \right). \tag{4}$$

In our model the selection bias arises because the price w_i is observed only when the i-th painting is sold (therefore $s_i = 1$) and when $\sigma_{u\varepsilon}$ is different from zero; in such a situation, Heckman (1979) shows that OLS estimation yields biased and inconsistent estimates of β.

Generally, the estimator for the Heckit model is the Maximum Likelihood (ML) under the assumption of joint normal distribution in equation (4); this method guarantees consistent and asymptotically normal and efficient estimates (see for example Greene, 1981). Unfortunately, in our analysis ML estimation of (2) does not achieve convergence, hence we use the Heckman's (1979) two-step procedure which yields a less efficient estimator.

The whole procedure can be briefly outlined as follows: given that $\phi(\cdot)$ and $\Phi(\cdot)$ respectively are the density and the cumulative density functions of the standardised Gaussian distribution, the first step consists of the ML estimation of the following probit model

$$\Pr(s_i = 1) = \Phi(z_i'\gamma). \tag{5}$$

Equation (5) predicts whether an item goes sold/unsold and it is useful to obtain the inverse of the Mills Ratio

$$\lambda_i = \frac{\phi(z_i'\gamma)}{\Phi(z_i'\gamma)}, \tag{6}$$

which will be used as an additional regressor during the second step to correct the potential sample selection bias.

Once λ_i is inserted in x_i vector, its coefficient is $\beta_\lambda = \sigma_{u\varepsilon}\sigma_\varepsilon^2$ and the second equation in (2) can be estimated via the OLS method. The covariance between u_i and ε_i can also be estimated and the standard t-statistic on β_λ is used to test if any problem of selection bias occurrs in our analysis.

Moreover, as shown by Pagan and Vella (1989), the assumption of normality of the probit residuals u_i is required to have consistency and plays a key role because it represents the sufficient condition to define λ_i as in equation (6). Following Davidson and MacKinnon (1993) we carried out the following conditional moment (CM) test based on the OPG Regression[16]

$$\iota = \hat{\gamma} Z + \hat{b} G + \text{residuals}, \tag{7}$$

where ι is a vector of ones, Z is the matrix whose each row is z_i' and $\hat{\gamma}$, $\hat{b}$ are ML estimates from the probit $\Pr(s_i = 1) = \Phi(z_i'\gamma + G_i'b)$. To take into account for asymmetry and kurtosis, the i-th row of the matrix G is

$$G_i' = \left[\; [(z_i'\hat{\gamma})^2 + 2]\hat{u}_i \qquad z_i'\hat{\gamma}[(z_i'\hat{\gamma})^2 + 3]\hat{u}_i \; \right], \tag{8}$$

where $\hat{u}_i$ are the model generalised residuals (see for example Pagan and Vella, 1989). It can be shown that, for each observation, G_i' contains the sample counterparts of the orthogonality conditions about the conditional moments $E(u_i^k | u_i < -z_i'\gamma)$, when k is 3 and 4 respectively (see Skeels and Vella, 1999).

The basic idea is that, if G_i' is not statistically relevant in the selection equation, the probit model (5) is correctly specified. Hence, the null hypothesis of the CM test is $H_0 : b = 0$ and the test statistic is given by N times the R^2 of the regression (7). Given that G has two columns, the asymptotic distribution is the standard χ^2_2.

In the next two sections a twofold approach will be tried: in section 4.2 a descriptive model for the auction prices is proposed, while in section 4.3 we discuss the problem of inserting the pre-sale estimates in the estimation of price in order to exploit more information.

4.2 Empirical results

After defining the partitioned vector $x_i = [\; \tilde{x}_i \;\vdots\; \mu_i \;]'$ containing all the explanatory variables, the starting point of our analysis consists of the Heckit estimation using the vector $\tilde{x}_i$ as regressor in the second step. In this context, the second equation in (2) can be thought as a sort of an hedonic regression in which the selection bias has been taken into account. All results for $w_i = y_i, Y_i$ are provided in Tables 3 and 4, while Table 5 contains some regression statistics; some explanatory variables among those presented in section 3.2.2 are dropped to avoid collinearity and, after some preliminary

[16] Outer Product Gradients Regression; see for example Davidson and MacKinnon (1993) for details.

estimates, other variables are excluded to reach the possible maximum reduction of parameters, without any loss of relevant information.

Table 3: Heckit estimation (1^{st} step)

	dependent variable: y_i				dependent variable: Y_i			
variable	coeff.	s.e.	t-stat	p-value	coeff.	s.e.	t-stat	p-value
constant	-0.0348	0.3226	-0.1078	0.9142	-0.0302	0.3227	-0.0936	0.9254
Characteristics of the artist								
Adami	-0.3406	0.2820	-1.2080	0.2271	-0.3431	0.2820	-1.2164	0.2238
Beecroft	-0.3884	0.5256	-0.7390	0.4599	-0.3935	0.5256	-0.7487	0.4540
Boetti	0.7326	0.2226	3.2916	0.0010***	0.7327	0.2226	3.2913	0.0010***
Burri	0.0056	0.2129	0.0265	0.9788	0.0043	0.2129	0.0204	0.9838
Campigli	0.3642	0.2116	1.7217	0.0851*	0.3651	0.2116	1.7254	0.0845*
Castellani	0.1181	0.2941	0.4015	0.6881	0.1163	0.2942	0.3953	0.6927
Cattelan	0.0390	0.5298	0.0735	0.9414	0.0365	0.5300	0.0689	0.9451
Chia	-0.2070	0.2846	-0.7273	0.4671	-0.2088	0.2846	-0.7336	0.4632
Clemente	-0.4006	0.2953	-1.3566	0.1749	-0.4131	0.2956	-1.3974	0.1623
Cucchi	0.0589	0.3183	0.1849	0.8533	0.0555	0.3184	0.1744	0.8616
Fontana	0.3571	0.1872	1.9070	0.0565*	0.3572	0.1873	1.9073	0.0565*
Kounellis	0.1475	0.3338	0.4418	0.6586	0.1325	0.3347	0.3958	0.6922
Magnelli	0.3987	0.2283	1.7467	0.0807*	0.3979	0.2283	1.7429	0.0813*
Manzoni	0.1895	0.2194	0.8637	0.3878	0.1894	0.2195	0.8630	0.3881
Marini	0.3642	0.2501	1.4561	0.1454	0.3661	0.2501	1.4637	0.1433
Melotti	-0.0838	0.4984	-0.1682	0.8664	-0.0814	0.4985	-0.1633	0.8703
Merz	-0.2495	0.3291	-0.7582	0.4483	-0.2513	0.3292	-0.7634	0.4453
Music	-0.1315	0.2613	-0.5034	0.6147	-0.1354	0.2613	-0.5181	0.6044
Paladino	-0.2377	0.2795	-0.8505	0.3950	-0.2476	0.2798	-0.8848	0.3763
Pomodoro	-1.1805	0.7890	-1.4962	0.1346	-1.1791	0.7895	-1.4935	0.1353
dead	-0.4077	0.1928	-2.1142	0.0345**	-0.4107	0.1929	-2.1288	0.0333**
Physical characteristics								
enamel	-0.6613	0.2568	-2.5752	0.0100**	-0.6560	0.2568	-2.5547	0.0106**
mixed	-0.0662	0.1202	-0.5512	0.5815	-0.0661	0.1202	-0.5499	0.5824
oil	0.0474	0.0921	0.5147	0.6068	0.0493	0.0921	0.5347	0.5928
tempera	0.0299	0.1208	0.2475	0.8046	0.0305	0.1208	0.2521	0.8010
other	0.1384	0.0942	1.4694	0.1417	0.1408	0.0942	1.4956	0.1348
canvas	0.0964	0.0781	1.2350	0.2168	0.0939	0.0781	1.2016	0.2295
paper	-0.0829	0.1009	-0.8217	0.4112	-0.0889	0.1011	-0.8798	0.3790
Artistic characteristics								
authentic	-0.0990	0.1075	-0.9214	0.3569	-0.0972	0.1075	-0.9044	0.3658
catalogue	-0.0161	0.0808	-0.1990	0.8423	-0.0167	0.0808	-0.2064	0.8365
exhibit	0.0185	0.0181	1.0227	0.3065	0.0188	0.0182	1.0341	0.3011
expertise	-0.0663	0.1374	-0.4824	0.6295	-0.0667	0.1374	-0.4852	0.6275
literature	-0.1379	0.0866	-1.5919	0.1114	-0.1369	0.0866	-1.5800	0.1141
owners	0.0152	0.0290	0.5236	0.6005	0.0146	0.0290	0.5023	0.6154
signature	0.0303	0.0670	0.4526	0.6508	0.0301	0.0670	0.4487	0.6536

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Table 3 — *continued from previous page*

	dependent variable: y_i				dependent variable: Y_i			
variable	coeff.	s.e.	t-stat	p-value	coeff.	s.e.	t-stat	p-value
Sale characteristics								
christies	0.6503	0.1018	6.3914	0.0000***	0.6510	0.1018	6.3977	0.0000***
sothebys	0.8105	0.1011	8.0196	0.0000***	0.8075	0.1011	7.9886	0.0000***
finarte	0.3952	0.1094	3.6134	0.0003***	0.3950	0.1094	3.6120	0.0003***
d_1991	0.2600	0.1696	1.5327	0.1254	0.2609	0.1696	1.5384	0.1240
d_1992	0.2926	0.1535	1.9063	0.0566*	0.2942	0.1535	1.9161	0.0554*
d_1993	-0.3722	0.1522	-2.4454	0.0145**	-0.3716	0.1522	-2.4418	0.0146**
d_1994	-0.1253	0.1445	-0.8671	0.3859	-0.1445	0.1452	-0.9953	0.3196
d_1995	0.0688	0.1504	0.4573	0.6475	0.0698	0.1504	0.4642	0.6425
d_1996	-0.0857	0.1412	-0.6070	0.5439	-0.0897	0.1414	-0.6344	0.5258
d_1997	-0.4023	0.1452	-2.7701	0.0056***	-0.4006	0.1452	-2.7586	0.0058***
d_1998	-0.1693	0.1530	-1.1062	0.2686	-0.1673	0.1530	-1.0931	0.2743
d_1999	0.1649	0.1392	1.1845	0.2362	0.1657	0.1392	1.1909	0.2337
d_2000	-0.1001	0.1415	-0.7076	0.4792	-0.0983	0.1415	-0.6949	0.4871
d_2001	-0.1726	0.1376	-1.2542	0.2098	-0.1712	0.1376	-1.2440	0.2135
d_2002	-0.2619	0.1353	-1.9349	0.0530*	-0.2605	0.1353	-1.9248	0.0543*
d_2003	-0.0511	0.1391	-0.3670	0.7136	-0.0500	0.1391	-0.3597	0.7191
d_2004	0.4562	0.1519	3.0036	0.0027***	0.4574	0.1519	3.0119	0.0026***
d_2005	0.1862	0.1379	1.3504	0.1769	0.1878	0.1379	1.3623	0.1731
d_2006	0.2148	0.1423	1.5097	0.1311	0.2162	0.1423	1.5197	0.1286

* indicates statistical significance at the 10% level.
** indicates statistical significance at the 5% level.
*** indicates statistical significance at the 1% level.

Table 4: Heckit estimation (2^{nd} step)

	dependent variable: y_i				dependent variable: Y_i			
variable	coeff.	s.e.	t-stat	p-value	coeff.	s.e.	t-stat	p-value
constant	3.3029	0.2448	13.4935	0.0000***	3.4341	0.2422	14.1780	0.0000***
Adami	-0.7652	0.2167	-3.5311	0.0004***	-0.7534	0.2145	-3.5120	0.0004***
Beecroft	-2.2322	0.4070	-5.4853	0.0000***	-2.2017	0.4027	-5.4670	0.0000***
Boetti	-0.4771	0.1710	-2.7909	0.0053***	-0.4796	0.1692	-2.8340	0.0046***
Burri	1.1525	0.1604	7.1865	0.0000***	1.1472	0.1587	7.2300	0.0000***
Campigli	1.2194	0.1589	7.6732	0.0000***	1.2137	0.1573	7.7170	0.0000***
Castellani	-0.1641	0.2136	-0.7679	0.4425	-0.1508	0.2114	-0.7130	0.4755
Cattelan	0.9315	0.3510	2.6537	0.0080***	0.9186	0.3474	2.6450	0.0082***
Chia	-0.5868	0.2137	-2.7464	0.0060***	-0.5754	0.2115	-2.7210	0.0065***
Clemente	-0.0013	0.2242	-0.0060	0.9952	0.0025	0.2225	0.0110	0.9910
Cucchi	-0.5377	0.2277	-2.3620	0.0182**	-0.5193	0.2253	-2.3050	0.0212**
Fontana	1.1076	0.1442	7.6810	0.0000***	1.0934	0.1427	7.6610	0.0000***
Kounellis	0.2706	0.2369	1.1422	0.2534	0.2745	0.2353	1.1660	0.2435
Magnelli	0.1114	0.1699	0.6556	0.5121	0.1116	0.1682	0.6640	0.5068
Manzoni	1.3272	0.1652	8.0327	0.0000***	1.3074	0.1635	7.9980	0.0000***

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Table 4 — *continued from previous page*

	dependent variable: y_i				dependent variable: Y_i			
variable	coeff.	s.e.	t-stat	p-value	coeff.	s.e.	t-stat	p-value
Marini	0.9097	0.1846	4.9268	0.0000***	0.8922	0.1827	4.8820	0.0000***
Melotti	-1.0547	0.4120	-2.5602	0.0105**	-1.0569	0.4076	-2.5930	0.0095***
Merz	-0.5038	0.2506	-2.0103	0.0444**	-0.4909	0.2480	-1.9800	0.0478**
Music	0.3222	0.2004	1.6073	0.1080	0.3218	0.1984	1.6220	0.1048
Paladino	-0.5513	0.2105	-2.6192	0.0088***	-0.5430	0.2086	-2.6020	0.0093***
Pomodoro	-0.4690	0.7805	-0.6009	0.5479	-0.4601	0.7720	-0.5960	0.5512
dead	-0.0305	0.1450	-0.2102	0.8335	-0.0225	0.1437	-0.1570	0.8755
enamel	0.1295	0.2290	0.5655	0.5718	0.1303	0.2265	0.5750	0.5652
mixed	0.0917	0.0856	1.0718	0.2838	0.0837	0.0847	0.9890	0.3229
oil	0.1565	0.0647	2.4192	0.0156**	0.1508	0.0641	2.3520	0.0187**
tempera	0.0706	0.0868	0.8137	0.4158	0.0685	0.0860	0.7970	0.4255
other	0.1607	0.0658	2.4430	0.0146**	0.1520	0.0652	2.3330	0.0197**
canvas	0.1537	0.0558	2.7551	0.0059***	0.1510	0.0552	2.7340	0.0063***
paper	-0.4449	0.0709	-6.2718	0.0000***	-0.4425	0.0705	-6.2800	0.0000***
surface	0.6517	0.0290	22.5074	0.0000***	0.6445	0.0287	22.4870	0.0000***
squared	-0.0528	0.0032	-16.5274	0.0000***	-0.0521	0.0032	-16.4930	0.0000***
Artistic characteristics								
authentic	0.1071	0.0794	1.3487	0.1775	0.1124	0.0785	1.4310	0.1524
catalogue	0.2797	0.0564	4.9577	0.0000***	0.2742	0.0558	4.9120	0.0000***
exhibit	0.0266	0.0105	2.5321	0.0113**	0.0258	0.0104	2.4870	0.0129**
expertise	-0.2376	0.0939	-2.5317	0.0114**	-0.2311	0.0929	-2.4880	0.0128**
literature	0.2850	0.0621	4.5891	0.0000***	0.2848	0.0614	4.6360	0.0000***
owners	0.1339	0.0192	6.9852	0.0000***	0.1310	0.0190	6.8990	0.0000***
signature	0.0585	0.0464	1.2613	0.2072	0.0562	0.0459	1.2230	0.2213
Sale characteristics								
*d_*1991	-0.4911	0.1108	-4.4328	0.0000***	-0.4956	0.1097	-4.5200	0.0000***
*d_*1992	-0.6814	0.1008	-6.7568	0.0000***	-0.6957	0.0998	-6.9680	0.0000***
*d_*1993	-0.7115	0.1202	-5.9177	0.0000***	-0.6991	0.1190	-5.8760	0.0000***
*d_*1994	-0.9473	0.1049	-9.0351	0.0000***	-0.9313	0.1051	-8.8590	0.0000***
*d_*1995	-0.8258	0.1017	-8.1168	0.0000***	-0.8069	0.1007	-8.0150	0.0000***
*d_*1996	-0.8497	0.0994	-8.5487	0.0000***	-0.8398	0.0987	-8.5100	0.0000***
*d_*1997	-0.8158	0.1147	-7.1096	0.0000***	-0.7942	0.1135	-6.9950	0.0000***
*d_*1998	-0.7270	0.1111	-6.5431	0.0000***	-0.7073	0.1099	-6.4340	0.0000***
*d_*1999	-0.6131	0.0933	-6.5709	0.0000***	-0.5975	0.0924	-6.4690	0.0000***
*d_*2000	-0.6601	0.1003	-6.5825	0.0000***	-0.6230	0.0992	-6.2790	0.0000***
*d_*2001	-0.7199	0.0992	-7.2536	0.0000***	-0.6781	0.0982	-6.9060	0.0000***
*d_*2002	-0.6017	0.1000	-6.0148	0.0000***	-0.5464	0.0990	-5.5210	0.0000***
*d_*2003	-0.5960	0.0970	-6.1416	0.0000***	-0.5321	0.0960	-5.5420	0.0000***
*d_*2004	-0.3894	0.0977	-3.9857	0.0001***	-0.3329	0.0967	-3.4410	0.0006***
*d_*2005	-0.1714	0.0929	-1.8446	0.0651*	-0.1082	0.0920	-1.1770	0.2393
*d_*2006	0.0564	0.0953	0.5914	0.5542	0.1278	0.0943	1.3550	0.1755
λ_i	-0.5537	0.1733	-3.1942	0.0014***	-0.5504	0.1722	-3.1970	0.0014***

* indicates statistical significance at the 10% level.
** indicates statistical significance at the 5% level.
*** indicates statistical significance at the 1% level.

Table 5: Regression statistics

Dependent variable	y_i	Y_i
Mean of dependent variable	4.0932	4.2402
Std. dev. of dependent variable	1.2911	1.2808
Total observations	2814	2810
Censored observations	803	803
Censored observations (%)	28.5	28.6
Error sum of squares	1078.65	1052.25
S.E. of residuals	0.4371	0.4373
$\hat{\sigma}^2_{\varepsilon}$	0.8231	0.8147
$\hat{\sigma}_{u\varepsilon}$	-0.6727	-0.6755
Akaike Information Criterion	3246.58	3243.88
Bayesian Information Criterion	3573.47	3570.69
Hannan-Quinn Information Criterion	3573.47	3361.82
McFadden R^2 (probit)	0.0685	0.0686
LR test (probit)	230.658	230.674
p-value	0.0000	0.0000
CM test for the normality of u_i	0.7481	0.6789
p-value	0.6879	0.7122
Joint normality test for residuals	157.402	162.969
p-value	0.0000	0.0000

The first emerging aspect is that the estimates of the auction prices of the Italian Contemporary Art paintings are quite similar for the logarithms of the hammer price (y_i) and of the total purchase price (Y_i): the presence of transaction fees does not seem to have any relevant impact upon our analysis, also considering that there are 4 missing values for P_i in our original sample (see the total observations in Table 5). The sample size reduction is due to three missing values in $surface$ and $squares$.

The null hypothesis of the CM test is strongly accepted in both cases and this supports the consistency of our estimates in which λ_i is not statistically different from the inverse of the Mills Ratio.

The t-statistic evaluated for λ_i indicates that some correction for the sample selection bias is needed and, for this reason, the Heckit model is superior to OLS.

The negative estimated value of the coefficient related to λ_i depends upon $\hat{\sigma}_{u\varepsilon} < 0$: this suggests that paintings that go sold are more likely to be those with a lower price, since cheaper paintings are likely to be bought by a wider group of potential buyers.

Moreover, the Box and Pierce (1970) normality test highlights that the model disturbances are not jointly normally distributed and this is probably the reason why the ML estimation process does not converge.

The contributions given by the explanatory variables in the two steps of the estimation are discussed below.

4.2.1 First step

Only the dummies related to painters Boetti, Campigli, Fontana and Magnelli positively contribute to the outcome of artwork transactions. This suggests that the paintings made by this group of artists are, on average, less likely to go unsold at auction, showing a strong tendence to be easily traded. If the artist is dead at the moment of sale the painting has a higher probability to go unsold, as highlighted by the negative and significant coefficient related to *dead*. The variable *birth* has been dropped according to the results of preliminary analysis in which it was found to be not statistically relevant in both steps of estimation.

Media and support do not play any relevant role upon the probabiliy that paintings go unsold; only items painted with *enamel* are less likely to be sold. Even if in our sample most of the paintings are made on canvas and paper (see Table 10), they do not affect the estimation.

All the variables used to capture the prestige and the popularity of the paintings do not seem to be relevant at this stage of the estimation, with the only exception being *literature* which has a very feeble effect (the p-value is about 0.11).

The outcome of the sale, in terms of sold/unsold work, is highly determined by the auction house where the sale is arranged. For the need of parsimony, we consider only Christie's, Sotheby's and Finarte where more than 90% of transactions are placed. All their coefficients are positive and highly significant. The findings about Christie's and Sotheby's are coherent with those of De la Barre, Docclo and Ginsburgh (1994) who argued that some auction houses are able to systematically influence the successful outcome of the sale since they often attract more high valued artistic works[17]. The result of Finarte could be intepreted as a consequence of the "home bias effect", that is a general preference of buyers for domestic art production, as pointed out by Candela and Scorcu (2004).

It has also been previously proved that the other auction houses, the city and month of sale do not seem to have an additional effect on the probability of going unsold.

[17] ≪....the quality of a painting , not captured by our characteristics, is partly picked up by the saleroom coefficients: a "good" Picasso would go to Christie's or Sotheby's New York, a less good one would be sold at Drouot's [...] it is impossibile to disentangle the two effects.≫

Some years affect the outcome of the sale more than others: in particular 1993, 1997 and 2002 show negative and statistically significance relationships, while 1992 and 2004 instead have a positive and significant parameter.

4.2.2 Second step

It is straightforward evident from Table 4 that almost all variables play a key role in determining auction prices and the impact given by the majority of painters seems to be decisive. The number of the exceptions is very small and the statistical significance attributed to Pomodoro is scarse probably because only two works belong to our sample (see Table 9).

The estimation highlights that Campigli and Fontana, who have a positive and significant impact upon the selection equation, also show an analogous effect upon the second step; on the contrary, the coefficient related to Boetti has the opposite sign of that in the selection equation. The paintings made by Burri, Cattelan, Manzoni and Marini also seem to reach market values higher, on average, than other artists, while the negative parameters related to different painters suggest that their works generally achieve lower prices.

The variable *dead* do not have any effect, while the variable *birth* is dropped because of its statistical irrelevance. From our model one can argue that the death of the artist before the moment of sale only increases the probability that paintings go unsold, but does not affect auction prices. This result is in contrast with both contributions of Agnello and Pierce (1996) and Worthington and Higgs (2006): the former paper showed an increase by 154% of the auction prices of American art when the artist was still alive, while the latter work found that paintings made by deceased artists are associated with a price increase of 100.58%.

Our estimation suggests that painting media do not have a relevant effect upon the total purchase price of a painting; the only exceptions are *oil* and the residual variable *other* for which the coefficients produce an increasing effect upon artwork prices. It is difficult to compare these findings with previous analyses especially because these contributions are sometimes limited to historical periods when only few media were known (see for instance Figini and Onofri, 2005) or restricted to single medium samples (Candela and Scorcu, 1997).

The contributions of the supports are heterogeneous because *canvas* seems to have a significant and positive influence upon painting prices, while *paper* has the opposite effect.

The coefficient signs of the variables regarding the size of paintings are those expected and coherent with the findings of Czujack (1997): in particular, the artwork prices can be described as a concave function in which

the surface and the squared surface have a positive and negative relationship respectively. This suggests that, if the size is augmented, the Italian Contemporary Art prices tend to increase at first, but then decrease when the painting becomes too large and difficult to hang.

Among the artistic characteristics of the paintings, the publication in catalogues, the number of exhibitions, the literature and the number of previous owners have a positive effect, while the variable *expertise* surprisingly shows negative contributions, contrary to our expectation. Variables *authentic* and *signature* do not have any effect upon the estimation, maybe because the prestige of some auction houses serves as a guarantee of authenticity.

The sale year substantially affects the final purchase price of Italian contemporary art paintings: each year from 1991 to 2004 shows statistically significant and negative coefficients, while years 2005 and 2006 do not seem to be relevant. From the economic perspective the series of these coefficients can be used to built the yearly price index I_t, with all other characteristics being equal. This index shows the contribution to auction prices dynamics given by years of sale and its equation is $I_t = 100 \cdot \exp\{\hat{\beta}_t\}$, where $t = 1991, 1992, \ldots, 2006$. Just the hammer price index is plotted in Figure 2 since the curve related to the total purchase price (Y_i) is very similar. The base year is 1990 in which $I_t = 100$. For both series this index substantially shows an increase from 1994, while only in 2006 it has a value greater than those of the base year. This is consistent with the evidence of the art market downturn experienced in the early ninetees (see, among others, Mei and Moses, 2002) and the upturn of the market in recent years.

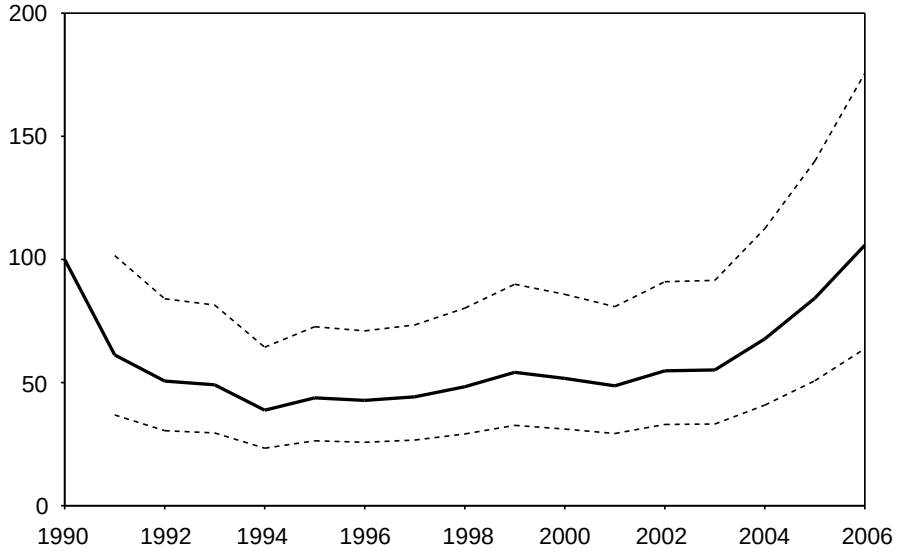
Finally, even if Table 3 highlights that principal auction houses strongly determine the outcome of sale, their contribution to price levels is not relevant and, for this reason, they have been dropped from the second the step of the estimation.

4.3 Sufficiency of pre-sale estimates

In this section we try to enhance our analysis by inserting the pre-sale estimates by experts in the estimation. In section 4.2 we showed a model which suffers from the loss of information due to the exclusion of μ_i provided by equation (1). Henceforth, we shall modify the Heckit specification including this variable in both the selection equation and the auction prices equation. As we said before, it can be a sufficient statistic (see section 3.2.2) for the price of paintings, therefore it can substantially change the information set available to buyers.

Table 6 reports the Heckit estimation for y_i, while Table 7 provides the

Figure 2: Price index for the Italian Contemporary Art paintings (I_t)



For each dependent variable, the dotted lines show the index confidence intervals given by $100 \cdot \exp\{\beta_t \pm 1.96 \cdot s.e.(\beta_t)\}$ for the t-th year.

regression statistics[18].

Table 6: Heckit estimation with pre-sale estimates

	selection equation (1^{st} step)				price equation (2^{nd} step)			
variable	coeff.	s.e.	t-stat	p-value	coeff.	s.e.	t-stat	p-value
constant	0.4419	0.3426	1.2899	0.1971	0.5028	0.1076	4.6733	0.0000***
Characteristics of the artist								
Adami	-0.3910	0.2852	-1.3710	0.1704	-0.1333	0.0958	-1.3911	0.1642
Beecroft	-0.5332	0.5277	-1.0104	0.3123	-0.5479	0.1799	-3.0461	0.0023***
Boetti	0.7072	0.2242	3.1544	0.0016***	0.0186	0.0741	0.2512	0.8016
Burri	0.1321	0.2181	0.6054	0.5449	0.2235	0.0714	3.1314	0.0017***
Campigli	0.5043	0.2153	2.3422	0.0192**	0.2066	0.0712	2.9031	0.0037***
Castellani	0.1578	0.2970	0.5312	0.5953	-0.0412	0.0937	-0.4394	0.6604
Cattelan	0.2059	0.5354	0.3845	0.7006	0.2276	0.1526	1.4918	0.1358
Chia	-0.1748	0.2871	-0.6088	0.5427	-0.1204	0.0938	-1.2830	0.1995

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[18]The estimation using Y_i as dependent variable is quite similar to that in Table 6, therefore it is omitted for brevity. Neverthless, in Table 7 regression statistics for both y_i and Y_i are shown, because there are some small differences. However, all the results are available upon request from the authors.

Table 6 — *continued from previous page*

	selection equation (1^{st} step)				price equation (2^{nd} step)			
variable	coeff.	s.e.	t-stat	p-value	coeff.	s.e.	t-stat	p-value
Clemente	-0.2594	0.2988	-0.8683	0.3852	-0.1420	0.0977	-1.4527	0.1463
Cucchi	0.0539	0.3216	0.1677	0.8668	0.0570	0.0999	0.5708	0.5682
Fontana	0.5125	0.1902	2.6940	0.0071***	0.2116	0.0648	3.2643	0.0011***
Kounellis	0.3279	0.3370	0.9729	0.3306	-0.0823	0.1038	-0.7913	0.4288
Magnelli	0.3905	0.2292	1.7039	0.0884*	-0.0163	0.0741	-0.2202	0.8257
Manzoni	0.3257	0.2215	1.4702	0.1415	0.2292	0.0737	3.1078	0.0019***
Marini	0.5784	0.2554	2.2650	0.0235**	0.2176	0.0818	2.6592	0.0078***
Melotti	-0.2532	0.5095	-0.4970	0.6192	0.0939	0.1823	0.5154	0.6062
Merz	-0.1867	0.3316	-0.5630	0.5734	-0.2016	0.1098	-1.8367	0.0663*
Music	-0.0931	0.2640	-0.3529	0.7242	0.0356	0.0881	0.4042	0.6860
Paladino	-0.1952	0.2823	-0.6913	0.4894	-0.0300	0.0925	-0.3240	0.7459
Pomodoro	-1.2733	0.7963	-1.5992	0.1098	0.3550	0.3509	1.0118	0.3116
dead	-0.3917	0.1955	-2.0035	0.0451**	-0.1177	0.0635	-1.8523	0.0640*
Physical characteristics								
enamel	-0.7129	0.2570	-2.7737	0.0055***	-0.0036	0.1014	-0.0354	0.9717
mixed	-0.0638	0.1214	-0.5258	0.5990	0.0012	0.0375	0.0327	0.9739
oil	0.0701	0.0940	0.7464	0.4554	-0.0032	0.0285	-0.1109	0.9117
tempera	0.0215	0.1221	0.1758	0.8604	-0.0120	0.0380	-0.3171	0.7512
other	0.1823	0.0955	1.9095	0.0562*	-0.0390	0.0289	-1.3491	0.1773
canvas	0.1505	0.0800	1.8807	0.0600*	-0.0006	0.0247	-0.0241	0.9808
paper	-0.1742	0.1031	-1.6896	0.0911*	-0.0783	0.0316	-2.4814	0.0131**
$surface$					0.0380	0.0149	2.5600	0.0105**
squared					-0.0035	0.0016	-2.2389	0.0252**
Artistic characteristics								
authentic	-0.0945	0.1093	-0.8650	0.3870	-0.0258	0.0351	-0.7362	0.4616
catalogue	0.0162	0.0828	0.1955	0.8450	-0.0003	0.0250	-0.0115	0.9908
exhibit	0.0406	0.0211	1.9195	0.0549*	0.0100	0.0046	2.1625	0.0306**
expertise	-0.0662	0.1400	-0.4728	0.6363	-0.0723	0.0408	-1.7737	0.0761*
literature	-0.0726	0.0885	-0.8201	0.4122	0.0230	0.0270	0.8531	0.3936
					-0.0014	0.0082	-0.1692	0.8657
signature	0.0284	0.0680	0.4175	0.6763	-0.0203	0.0203	-0.9995	0.3176
Sale characteristics								
christies	0.6955	0.1028	6.7631	0.0000***				
sothebys	0.8419	0.1022	8.2362	0.0000***				
$finarte$	0.3723	0.1098	3.3902	0.0007***				
d_1991	0.1841	0.1731	1.0641	0.2873	-0.1407	0.0483	-2.9121	0.0036***
d_1992	0.1908	0.1588	1.2016	0.2295	-0.1980	0.0444	-4.4623	0.0000***
d_1993	-0.4870	0.1556	-3.1291	0.0018***	-0.1206	0.0541	-2.2281	0.0259**
d_1994	-0.2466	0.1504	-1.6391	0.1012	-0.1334	0.0473	-2.8189	0.0048***
d_1995	-0.0713	0.1549	-0.4600	0.6455	-0.1186	0.0451	-2.6300	0.0085***
d_1996	-0.1821	0.1463	-1.2451	0.2131	-0.2006	0.0443	-4.5270	0.0000***
d_1997	-0.5290	0.1501	-3.5249	0.0004***	-0.1540	0.0521	-2.9553	0.0031***
d_1998	-0.2622	0.1580	-1.6591	0.0971*	-0.0979	0.0494	-1.9829	0.0474**
d_1999	0.0727	0.1434	0.5069	0.6122	-0.0397	0.0408	-0.9728	0.3307

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Table 6 — *continued from previous page*

	selection equation (1^{st} step)				price equation (2^{nd} step)			
variable	coeff.	s.e.	t-stat	p-value	coeff.	s.e.	t-stat	p-value
d_2000	-0.1936	0.1453	-1.3325	0.1827	-0.0364	0.0448	-0.8120	0.4168
d_2001	-0.2807	0.1420	-1.9772	0.0480**	-0.0533	0.0447	-1.1930	0.2329
d_2002	-0.3576	0.1388	-2.5755	0.0100**	-0.0886	0.0448	-1.9790	0.0478**
d_2003	-0.1203	0.1416	-0.8494	0.3957	0.0208	0.0432	0.4808	0.6307
d_2004	0.3955	0.1543	2.5640	0.0103**	0.0629	0.0422	1.4895	0.1363
d_2005	0.1872	0.1394	1.3430	0.1793	0.0810	0.0406	1.9921	0.0464**
d_2006	0.2091	0.1427	1.4653	0.1428	0.1457	0.0416	3.5053	0.0005***
μ_i	-0.1486	0.0325	-4.5709	0.0000***	0.9155	0.0113	80.7153	0.0000***
λ_i					-0.1580	0.0728	-2.1718	0.0299**

* indicates statistical significance at the 10% level.
** indicates statistical significance at the 5% level.
*** indicates statistical significance at the 1% level.

Table 7: Regression statistics

Dependent variable	y_i	Y_i
Mean of dependent variable	4.0762	4.2234
Std. dev. of dependent variable	1.2871	1.2769
Total observations	2774	2770
Censored observations	786	786
Censored observations (%)	28.3	28.4
Error sum of squares	218.516	213.781
S.E. of residuals	0.4344	0.4345
$\hat{\sigma}^2_{\varepsilon}$	0.3483	0.3481
$\hat{\sigma}_{u\varepsilon}$	-0.4539	-0.4937
Akaike Information Criterion	1364.14	1322.16
Bayesian Information Criterion	1677.46	1635.36
Hannan-Quinn Information Criterion	1479.22	1437.21
McFadden R^2 (probit)	0.0757	0.0759
LR test (probit)	250.512	250.996
p-value	0.0000	0.0000
CM test for the normality of u_i	1.1366	1.0016
p-value	0.5665	0.6060
Joint normality test for residuals	801.798	723.945
p-value	0.0000	0.0000

Both estimations for $w_i = y_i, Y_i$ are carried out dropping 43 observations from the sample which depend upon the 40 missing values from series μ_i (see Table 12) plus the 3 unavailable data values in series $surface$ and $squares$.

The pre-sale estimates have a relevant impact in both steps of estimation. On one hand, the strong and negative effect upon the probability to have sold/unsold items at auction can be explained from two points of view: from the statistical perspective, μ_i seems to represent essential information while,

from the economic perspective, paintings that sell easily are those with low potential market values. This is coherent with the strategy of auction houses that often keep pre-sale evaluations low to attract more buyers. On the other hand, the strongly positive coefficient in the second step reveals that this variable plays a decisive influence upon final painting prices; this suggests that the higher the pre-sale evaluation by experts, the higher the final auction prices are.

Some variables that appeared relevant in the previous analysis, seem to lose their explanatory power when the pre-sale estimates by experts are included. Nevertheless, these results are not immediately comparable with those of the previous estimation, especially because some problems regarding the economic interpretation of the estimation can arise from the use of x_i intead of $\tilde{x}_i$; these problems are connected to the possible sufficiency of μ_i which has to be discussed and checked.

Supposing that the experts' information set $\mathcal{I}$ is larger than that of the buyers $\mathcal{F}$, hence $\mathcal{F} \subset \mathcal{I}$. If the experts have rational expectations and a quadratic cost (loss) function $L(\cdot)$, $E[L(w_i - \mu_i|\mathcal{I})]$ is minimised and the best predictor is given by the conditional mean

$$E(w_i|\mathcal{I}) = \mu_i. \tag{9}$$

The variable μ_i is a sufficient statistic for auction prices if, using the law of iterated expectations, it follows that

$$E(w_i|\mathcal{F}, \mu_i) = \mu_i. \tag{10}$$

However, our empirical analysis does not support this condition: to address this problem Table 8 shows some Wald tests for the parameters in the second step estimation. From the theoretical point of view these tests should be carried out for the system of simultaneous equations

$$\begin{cases} \mu_i = \tilde{x}_i' b + \eta_i & \text{for } i = 1, 2, \ldots, N \\ w_i = a\mu_i + \tilde{x}_i' b + \xi_i & \text{for } i = 1, 2, \ldots, n. \end{cases} \tag{11}$$

Unfortunately, the unsold works reduce the number of observations to $n < N$, therefore the estimation of (11) is not possible and our Heckit specification represents a sort of approximation.

The null hypotheses tested are:

- $a = 0$: auction prices do not depend upon pre-sale estimates. This is the condition under which the model in section 4.2 has been estimated;
- $a = 1$: auction prices strictly depend upon pre-sales estimates, μ_i is an unbiased predictor and b is the impact of $\tilde{x}_i$ upon the difference between auction prices and the pre-sale evaluation;

- $b = 0$: all the explanatory variables in $\tilde{x}_i$ do not contain any relevant information once pre-sale evaluation is considered in the model;
- $a = 1$ and $b = 0$: auction prices only depend upon pre-sale estimates, hence $\tilde{x}_i$ do not have any effect upon the difference $(w_i - \mu_i)$. In this case, μ_i is unbiased, efficient and also contains all the available information.

Table 8: Parameter restrictions

Dep. Variable	y_i	Y_i	Dep. Variable	y_i	Y_i
H_0	α=0		H_0	$b = 0$	
Test Statistic	6514.96	6392.1	Test Statistic	211.668	272.726
p-value	0.0000	0.0000	p-value	0.0000	0.0000
H_0	$\alpha = 1$		H_0	$\alpha = 1, b = 0$	
Test Statistic	55.4488	68.9696	Test Statistic	226.675	300.737
p-value	0.0000	0.0000	p-value	0.0000	0.0000

All the hypotheses are strongly rejected and this supports the idea that, even if pre-sale estimates represent a relevant price determinant of the Italian Contemporary Art paintings at auction, they are not a sufficient statistic.

There are three possible reasons for $E(w_i|\mathcal{F}, \mu_i) \neq \mu_i$: first, pre-sale estimates can suffer from some market inefficiency (non rational expectations) for which the hypothesis (9) is violated[19]. Second, the loss fuction of the experts could not be quadratic as hypothized by the rational expectations theory; moreover, some asymmetries could arise especially because experts tend to underestimate m_i and M_i to make paintings more attractive to buyers. Third, the log transformation of auction prices can induce some distortion especially because, according to the Jensen's Lemma, the expectations about logarithms are different from the logarithms of the expectations.

However, even if an important determinant for auction prices is inserted in the model, the problem of the coefficients interpretability of the other variables arises: in practice, if the estimated parameters of the other explanatory factors are statistically relevant, this result would be interpreted as an additional effect which is not captured by the pre-sale estimates. To the contrary, often it is difficult to distinguish if the irrelevance of certain parameters is due to the presence of μ_i or not.

In theory, the information properties of this model can be useful in a predictive setup, but this possibility is prevented by the unavailabilty of certain variables as, for example, the year of sale or the painters not included in our sample.

[19]Pre-sale estimates are generally available some months before the sale, but in the meanwhile some new information could arise.

5 Concluding remarks

This paper aims to model the prices of paintings given a set of explanatory variables regarding different characteristics. The whole analysis is carried out after creating a sample of 2817 transactions of paintings made by 21 Italian contemporary painters and sold at auction during the period 1990-2006. To take the problem of sample selection bias arising from the inclusion of unsold paintings into account, the Heckit model (Heckman, 1979) is used to obtain consistent estimates.

Our estimation highlights that some mechanism of selection bias occurrs hence this methodology is superior to OLS. The main finding is that auction prices for the Italian Contemporary Art market depend upon several variables such as auction house prestige, year of sale, artist's popularity and different artistic characteristics of paintings (publication in catalogues, number of exhibitions, citations in the artistic literature, number of previous owners). This finding is consistent with the main existing literature.

Contrary to previous studies (see for example, Czujack, 1997 or Worthington and Higgs, 2006), we found that traditional media, supports and conventional proxies of artistic qualities are less able to explain the marketability of paintings, while they have a strong effect on price levels. Other variables playing a leading role upon the outcome of sale are those related to sale characteristics (for example, auction house prestige) and to the years in which the transactions take place; the years of sale also affect the auction price determination.

A price index that fits the cyclical nature of the Italian Contemporary Art market has been derived from the coefficients related to the years of sale: after an initial decline it tends to increase from 1994 and finally have a strong rise after 2003. This evidence reflects the downturn of the art market in the early ninetees and it is coherent with previous literature. Some suggested reasons for this cycle could be macroeconomic factors such as the dependence of the art market upon per capita income (Frey and Pommerehne, 1991), financial courses such as the correlation between art market cycles and bullish/bearish financial markets (Chanel, 1995) or simply art fads such as collectors' changing attitudes towards contemporary art (Buelens and Ginsburg, 1993).

Moreover, we also try to estimate a model by inserting the pre-sale estimates provided by experts (μ_i). We find that they are not a sufficient statistic for auction prices, but they are crucial in both steps of the Heckit estimation: they serve as a deterrent to buyers when they are high but, at the same time, they are the main driving factors for prices when paintings are sold. The use of this explanatory variable enhances the model efficiency, but, from the economic perspective, also generates a problem of coefficient

interpretability: when the estimated coefficients of the other explanatory variables are significant their impact can be seen as a sort of a net effect. Otherwise, when the coefficients are not statistically relevant, it is hard to evaluate if this result depends upon the presence of μ_i or not.

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Appendix: List of variables

Table 9: Characteristics of the artist (N=2817)

variable	description	birth	dead	obs.
Name of the artist				
Adami	1 if the author is Valerio Adami, 0 otherwise	1935	-	170
Beecroft	1 if the author is Vanessa Beecroft, 0 otherwise	1966	-	9
Boetti	1 if the author is Alighiero Boetti, 0 otherwise	1940	1994	212
Burri	1 if the author is Alberto Burri, 0 otherwise	1915	1995	126
Campigli	1 if the author is Massimo Campigli, 0 otherwise	1895	1971	268
Castellani	1 if the author is Enrico Castellani, 0 otherwise	1930	-	114
Cattelan	1 if the author is Maurizio Cattelan, 0 otherwise	1960	-	10
Chia	1 if the author is Sandro Chia, 0 otherwise	1946	-	155
Clemente	1 if the author is Francesco Clemente, 0 otherwise	1952	-	101
Cucchi	1 if the author is Enzo Cucchi, 0 otherwise	1950	-	65
Fontana	1 if the author is Lucio Fontana, 0 otherwise	1899	1968	720
Gnoli	1 if the author is Domenico Gnoli, 0 otherwise	1933	1970	64
Kounellis	1 if the author is Jannis Kounellis, 0 otherwise	1936	-	51
Magnelli	1 if the author is Alberto Magnelli, 0 otherwise	1888	1971	105
Manzoni	1 if the author is Piero Manzoni, 0 otherwise	1934	1963	137
Marini	1 if the author is Marino Marini, 0 otherwise	1901	1980	68
Melotti	1 if the author is Fausto Melotti, 0 otherwise	1901	1986	8
Merz	1 if the author is Mario Merz, 0 otherwise	1925	-	41
Music	1 if the author is Zoran Music, 0 otherwise	1909	2005	241
Paladino	1 if the author is Mimmo Paladino, 0 otherwise	1948	-	150
Pomodoro	1 if the author is Arnaldo Pomodoro, 0 otherwise	1926	-	2
Living status				
Dead	1 if the painter is dead at the moment of selling, 0 otherwise			1705
Year of birth				
Birth	Year of birth			

Source: Artindex Plus - Gabrius S.p.A.

Table 10: Physical characteristics (N=2817)

variable	description	obs.
Medium		
collage	1 if the medium is collage, 0 otherwise	5
enamel	1 if the medium is enamel, 0 otherwise	29
gouache	1 if the medium is gouache, 0 otherwise	1
mixed	1 if the medium is mixed, 0 otherwise	385
pencil	1 if the medium is pencil, 0 otherwise	2
oil	1 if the medium is oil, 0 otherwise	1429
tempera	1 if the medium is tempera, 0 otherwise	320
other	1 if the medium is other, 0 otherwise	1037
Support		
board	1 if the support is board, 0 otherwise	185
canvas	1 if the support is canvas, 0 otherwise	2254
cartoon	1 if the support is cartoon, 0 otherwise	173
$fabric$	1 if the support is fabric, 0 otherwise	75
marble	1 if the support is marble, 0 otherwise	5
masonite	1 if the support is masonite, 0 otherwise	26
panel	1 if the support is panel, 0 otherwise	166
paper	1 if the support is paper, 0 otherwise	275
wood	1 if the support is wooden base, 0 otherwise	7
support	1 if the support is other, 0 otherwise	146
Size		
$surface$	Painting area (in m^2)	
squared	Painting squared area	

Source: Artindex Plus - Gabrius S.p.A.

Note: for some paintings different media or different supports are jointly used.

Table 11: Artistic characteristics (N=2817)

variable	description	obs.
authentic	1 if the painter has confirmed the authenticity, 0 otherwise	187
catalogue	1 if the painting is published on catalogs/monographies, 0 otherwise	680
date	1 if the painting is dated, 0 otherwise	1700
expertise	1 if the painting is recognised by experts, 0 otherwise	132
literature	1 if the painting is cited in literature, 0 otherwise	1049
signature	1 if the painting is signed, 0 otherwise	2071
title	1 if the painting is titled, 0 otherwise	1722
exhibit	Number of exhibitions	
owners	Number of previous owners	

Source: Artindex Plus - Gabrius S.p.A.

Table 12: Sale characteristics (N=2817)

variable	description	obs.
Auction houses		
Curial	1 if the painting was sold at Art Curial, 0 otherwise	36
Bonhams	1 if the painting was sold at Bonhams, 0 otherwise	4
Bruun	1 if the painting was sold at Bruun Rasmussen, 0 otherwise	2
Bukowskis	1 if the painting was sold at Bukowskis, 0 otherwise	2
Camels	1 if the painting was sold at Camels Cohen, 0 otherwise	2
Christies	1 if the painting was sold at Christie's, 0 otherwise	914
Dorotheum	1 if the painting was sold at Dorotheum, 0 otherwise	9
Doyle	1 if the painting was sold at Doyle, 0 otherwise	2
Finarte	1 if the painting was sold at Finarte Semenzato, 0 otherwise	536
Grisebach	1 if the painting was sold at Grisebach, 0 otherwise	8
Koller	1 if the painting was sold at Koller, 0 otherwise	5
Lempertz	1 if the painting was sold at Lempertz, 0 otherwise	39
Neumeister	1 if the painting was sold at Nuemeister, 0 otherwise	3
Pandolfini	1 if the painting was sold at Pandolfini, 0 otherwise	1
Phillips	1 if the painting was sold at Phillips, 0 otherwise	37
Piasa	1 if the painting was sold at Piasa, 0 otherwise	1
Porro	1 if the painting was sold at Porro & C., 0 otherwise	27
Sothebys	1 if the painting was sold at Sotheby's, 0 otherwise	1137
Tajan	1 if the painting was sold at Tajan, 0 otherwise	43
Marketplace		
Amsterdam	1 if the painting was sold in Amsterdam, 0 otherwise	4
NY	1 if the painting was sold in New York, 0 otherwise	363
Berlin	1 if the painting was sold in Berlin, 0 otherwise	8
Paris	1 if the painting was sold in Paris, 0 otherwise	88
Cologne	1 if the painting was sold in Cologne, 0 otherwise	39
Copenhagen	1 if the painting was sold in Copenhagen, 0 otherwise	2
London	1 if the painting was sold in London, 0 otherwise	1109
LA	1 if the painting was sold in Los Angeles, 0 otherwise	4
Lugano	1 if the painting was sold in Lugano, 0 otherwise	17
Milan	1 if the painting was sold in Milan, 0 otherwise	994
Montecarlo	1 if the painting was sold in Montecarlo, 0 otherwise	3
Munich	1 if the painting was sold in Munich, 0 otherwise	3
Rome	1 if the painting was sold in Rome, 0 otherwise	140
Stockholm	1 if the painting was sold in Stokholm, 0 otherwise	11
Sidney	1 if the painting was sold in Sidney, 0 otherwise	1
Venice	1 if the painting was sold in Venice, 0 otherwise	17
Vienna	1 if the painting was sold in Vienna, 0 otherwise	9
Zurich	1 if the painting was sold in Zurich, 0 otherwise	5
Sale date		
d_1990	1 if the painting was sold in 1990, 0 otherwise	242
d_1991	1 if the painting was sold in 1991, 0 otherwise	100
d_1992	1 if the painting was sold in 1992, 0 otherwise	140
d_1993	1 if the painting was sold in 1993, 0 otherwise	109

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Table 12 — *continued from previous page*

variable	description	obs.
d_1994	1 if the painting was sold in 1994, 0 otherwise	133
d_1995	1 if the painting was sold in 1995, 0 otherwise	135
d_1996	1 if the painting was sold in 1996, 0 otherwise	148
d_1997	1 if the painting was sold in 1997, 0 otherwise	127
d_1998	1 if the painting was sold in 1998, 0 otherwise	116
d_1999	1 if the painting was sold in 1999, 0 otherwise	190
d_2000	1 if the painting was sold in 2000, 0 otherwise	158
d_2001	1 if the painting was sold in 2001, 0 otherwise	182
d_2002	1 if the painting was sold in 2002, 0 otherwise	201
d_2003	1 if the painting was sold in 2003, 0 otherwise	206
d_2004	1 if the painting was sold in 2004, 0 otherwise	187
d_2005	1 if the painting was sold in 2005, 0 otherwise	332
d_2006	1 if the painting was sold in 2006, 0 otherwise	211
jan	1 if the painting was sold in January, 0 otherwise	1
feb	1 if the painting was sold in February, 0 otherwise	161
mar	1 if the painting was sold in March, 0 otherwise	245
apr	1 if the painting was sold in April, 0 otherwise	134
may	1 if the painting was sold in May, 0 otherwise	564
jun	1 if the painting was sold in June, 0 otherwise	466
jul	1 if the painting was sold in July, 0 otherwise	38
aug	1 if the painting was sold in August, 0 otherwise	5
sep	1 if the painting was sold in September, 0 otherwise	4
oct	1 if the painting was sold in October, 0 otherwise	433
nov	1 if the painting was sold in November, 0 otherwise	519
dec	1 if the painting was sold in December, 0 otherwise	347
Pre-sale evaluation		
μ_i	See equation (1)	2777

Fonte: Artindex Plus - Gabrius S.p.A.