

# Statistical Methods Used for Identification of Art Prices Determinants

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*Abstract:* - The paper deals with the problem of determinants of the auction prices of the works of art. A special attention is given to the attributes of works of art i.e.: the name of artist, time of creation, format (size), theme, technique, signature and their influence on the level of auction prices. The author of the paper uses statistical methods to verify empirically the relationship between variables. The dependences have been explained by implementation of three methods i.e.: analysis of variance ANOVA, multiple regression models and classification trees, with the use of the computer program *STATISTICA*. The analysis is based on the cross-section data on art auction results of several auction sessions in Poland. The empirical studies have shown that name of artist, year of creation and technique determine the auction prices of works of art. The influence of technique and signature is not important statistically.

*Key Words:* - art market, art value, prices of the works of art, art prices' determinants, statistical analysis, ANOVA (analysis of variance), multiple regression, classification trees (CART).

## 1 Introduction

The level of art prices on the auction market is affected by a number of economic, non-economic, internal, external, objective and subjective factors [2, 3, 4, 7, 10, 12, 18]. The determinants of art prices are connected with the work of art, with sellers, with buyers, with auctioneer, with market circumstances (regulations, institutions, artists' status, promotions) and art market environment (economic situation, exchange rate, situation on the stock exchange, import and export of art, art schools, art foundations, fairs, etc.).

The paper aims to identify the relations between the objective qualities of the pieces of art and their prices on the auction market. The qualities of a piece of art which may affect its price include its author, the time of origin, format (size), technique applied by artist, theme and signature. Such features, both in terms of quantity and quality character, constitute a set of non-dependent variables which have an impact on a dependent variable – the level price of the work of art. The identification of the above relations is based on the following statistical tools: analysis of variance (ANOVA), multiple regression and classification trees. The author focuses on the obtained results and their interpretation – not on the methodological aspects of the conducted analyses – these are discussed in detail in a number of manuals in the field of statistics and econometrics [20, 24, 25, 27].

## 2 ANOVA used for identification of the art prices' determinants

The significant differences between average auction art prices in the particular categories of selected variables are tested on the basis of ANOVA (*analysis of variance*)<sup>1</sup>. The analysis of variance was preceded by the testing of its assumptions including normality of distribution in the particular categories of the independent variables and Leven's test for homogeneity of variance. It should be noted that it was necessary to remove outlying observations from the set of data. The Tables present the results of variance analysis for the particular qualities of the pieces of art: the time of origin – (Table 1), format (Table 2), applied techniques (Table 3), theme (Table 4), signature (Table 5)<sup>2</sup>.

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<sup>1</sup> The principles of variance analysis: normal distribution of the price for each category of independent variable, equal variances for each category. The null hypothesis  $H_0$  – an average price level in all the selected groups (for example different groups of the time of origin) is the same. Null hypothesis  $H_0$  - average price levels in the distinguished groups are significantly different.

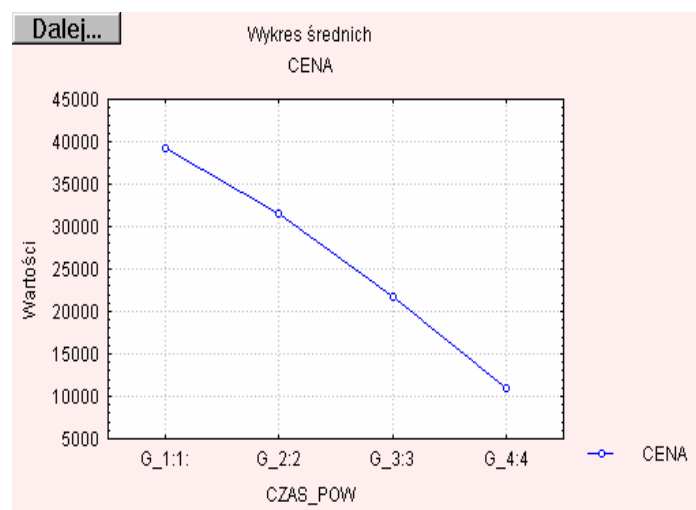
<sup>2</sup> The independent variables have been divided into several categories. Format has been considered as length multiply by height of the painting.

Table 1. Results of one-factor variance analysis (dependent variable – auction price level, independent variable – time of origin of a work of art)<sup>3</sup>

Selected samples	Results of variance analysis	Conclusions	Association time of origin – art price
Auction 1	P=0.042047 F=2.812302	Significant association	the older the piece of art the higher the price
Auction 2	P=0.004522 F=4.677990	Significant association	the older the piece of art the higher the price
Auction 3	P=0.042704 F=2.787961	Significant association	the older the piece of art the higher the price

Source: author's own research

Fig. 1. Time of origin of work of art versus auction price level



Source: author's own research in Statistica programme

Fig. 1 presents the relation between the time of origin of a piece of art and its auction price level. The highest price levels are characteristic of the oldest pieces, while the lowest prices are set for contemporary works of art.

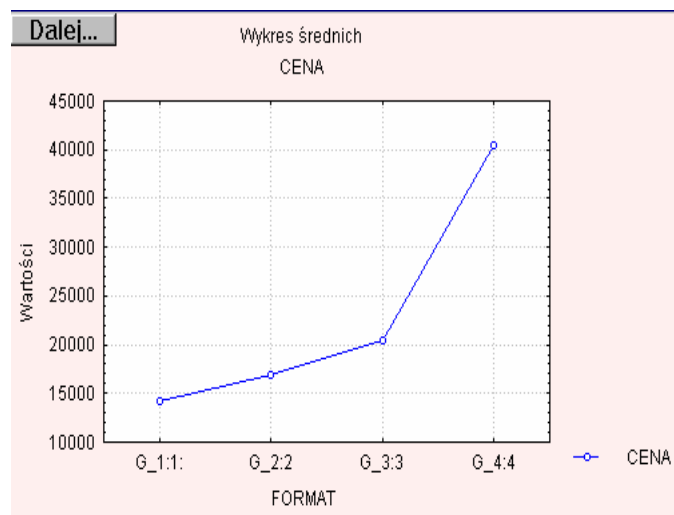
<sup>3</sup> F – Fisher-Snedecor's statistics – a basis for determining the critical area for the null hypothesis concerning the equality of all average values. F values close to one lead to accepting the tested hypothesis, values exceeding one lead to rejection, P – level of significance.

Table 2. Results of one-factor variance analysis (dependent variable – auction price level, independent variable – format of a piece of art)

Selected samples	Results of variance analysis	Conclusions	Association format – art price
Auction 1	P=0.000230 F=6.830050	Significant association	The larger the format the higher the price
Auction 2	P=0.000078 F=7.683252	Significant association	The larger the format the higher the price
Auction 3	p=0.001406 F=5.341527	Significant association	The larger the format the higher the price

Source: author's own research

Fig. 2. Format of the work of art versus auction price level



Source: author's own research in Statistica programme

There is a statistically significant association between the format of a piece of art and its auction price level. The larger the format the higher the price of the work of art.

Table 3. Results of one-factor variance analysis (dependent variable – auction price, independent variable – technique applied by artist)

Selected samples	Result of variance analysis	Conclusions
Auction 1	P=0.004576 F=4.523844	Significant association
Auction 2	P=0.046735 F=2.710823	Significant association
Auction 3	p=0.013956 F=3.613464	Significant association

Source: author's own research in Statistica programme

Table 4. Results of one-factor variance analysis ANOVA (dependent variable – auction price, independent variable – theme of a piece of art)

Selected samples	Result of variance analysis	Conclusions
Auction 1	P=0.184861 F=1.627896	Insignificant association
Auction 2	P=0.763218 F=0.386011	Insignificant association
Auction 3	P=0.604423 F=0.617250	Insignificant association

Source: author's own research in Statistica programme

Table 5. Results of one-factor variance analysis (dependent variable – auction price, independent variable – signing a piece of art by artist)

Selected samples	Result of variance analysis	Conclusions
Auction 1	P=0.559371 F=0.342158	Insignificant association
Auction 2	P=0.122259 F=2.412701	Insignificant association
Auction 3	P=0.558621 F=0.343021	Insignificant association

Source: author's own research in Statistica programme

The results of the conducted variance analysis indicate an impact of the time of origin, format and applied technique on the auction price of a piece of art. It should be noted that conducting a multi-factor variance analysis was not possible due to the insufficient number of observations in sub-groups.

### 3 Multiple regression used for identification of art prices' determinants

In examining the impact of selected factors on the auction prices of pieces of art the multiple regression procedure is applied, which explains the values of the dependent variable depending on the values of independent variables. The following variables are incorporated into the set of independent variables: author, time of origin, format, applied technique, theme, signature. The next phase of the analysis is the estimation of parameters included in the regression model based on the data obtained from selected auctions. The results of the estimation of the model's parameters obtained on the basis of the classical least square method are presented in Tables 6, 7 and 8. In the process of construing regression models the statistical verification of the significance of the obtained models is also carried out (Fisher-Snedecor's

F test), and the significance of the obtained parameters of the regression function for the particular variables (test t-Student) at the significance level of  $\alpha = 0.05$ .<sup>4</sup> It should be noted that the multiple modifications of models was necessary during the modelling process due to weak matching. The elimination of deviant and extreme observations always led in the conducted analysis to a considerable improvement in the degree of matching the model with empirical data (coefficients of determination  $R^2$ ).<sup>5</sup>

Table 6. Results of regression analysis for auction 1

R = 0.71994823, $R^2 = 0.51832545$ Corrected $R^2 = 0.47607330$ F(10.114) = 12.267 $p < 0.00000$ Standard error of estimate = 12 260						
	Beta	Standard error beta	B	Standard error B	T	P
A	<b>0.513543</b>	<b>0.072019</b>	<b>18342.9</b>	<b>2572.39</b>	<b>7.13069</b>	<b>0.000000</b>
T	<b>-0.203397</b>	<b>0.073733</b>	<b>-103.4</b>	<b>37.47</b>	<b>-2.75856</b>	<b>0.006765</b>
F	<b>0.373791</b>	<b>0.073770</b>	<b>2.1</b>	<b>0.41</b>	<b>5.06698</b>	<b>0.000002</b>
Th A	0.029657	0.093725	1135.1	3587.22	0.31643	0.752258
Th B	0.036288	0.098047	1231.1	3326.36	0.37011	0.711991
Th C	0.032992	0.080122	1889.4	4588.54	0.41178	0.681277
T A	<b>0.321562</b>	<b>0.104291</b>	<b>11794.2</b>	<b>3825.17</b>	<b>3.08331</b>	<b>0.002568</b>
T B	<b>0.293101</b>	<b>0.103677</b>	<b>9795.2</b>	<b>3464.78</b>	<b>2.82707</b>	<b>0.005574</b>
T C	<b>0.303142</b>	<b>0.113115</b>	<b>10604.9</b>	<b>3957.14</b>	<b>2.67995</b>	<b>0.008454</b>
S	0.067547	0.071979	3868.4	4122.21	0.93842	0.350011

Table 7. Results of regression analysis for auction 2

R = 0.72519036 $R^2 = 0.52590105$ Corrected $R^2 = 0.45912656$ F(10.71) = 7.8758 $p < 0.00000$ Standard error of estimate = 11 237						
	Beta	Standard error beta	B	Standard error B	T	P
A	<b>0.435939</b>	<b>0.955810</b>	<b>15006.9</b>	<b>3290.3</b>	<b>4.56094</b>	<b>0.000020</b>
T	<b>-0.206544</b>	<b>0.094624</b>	<b>-117.7</b>	<b>53.9</b>	<b>-2.18280</b>	<b>0.032313</b>
F	<b>0.358059</b>	<b>0.088628</b>	<b>1.0</b>	<b>0.26</b>	<b>4.04002</b>	<b>0.000134</b>
Th A	0.06444	0.093416	3413.3	4947.70	0.68987	0.492352
Th B	0.15618	0.119592	6134.7	4697.47	1.30595	0.195458
Th C	0.10241	0.068030	14688.5	9757.27	1.50539	0.136316
T A	<b>0.316977</b>	<b>0.122230</b>	<b>15850.3</b>	<b>6112.1</b>	<b>2.59328</b>	<b>0.011324</b>
T B	<b>0.227359</b>	<b>0.094185</b>	<b>27474.6</b>	<b>11381.6</b>	<b>2.41395</b>	<b>0.018094</b>
T C	<b>0.281960</b>	<b>0.129198</b>	<b>16519.4</b>	<b>7569.4</b>	<b>2.18238</b>	<b>0.032014</b>
S	0.127159	0.091248	35555.7	25514.5	1.39355	0.167313

A – author; T – time of origin; F – format; Th – theme; t – technique; S – signature. *Statistically significant regression coefficients for the variables incorporated into the analysis are in bold type.*

Source: author's own research in Statistica programme

<sup>4</sup> Statistics F serve to verify the model's significance. The null hypothesis claims that independent variables may not have a significant impact on the dependent variable (price). The rejection of the null hypothesis in test F confirms the statement that the regression equation explains the changeability of the dependent variable to a statistically significant degree. The values of Student's t-test make it possible to verify the significance of the regression parameters.

<sup>5</sup> All the pieces of art sold at a price exceeding PLN 100,000, some „outlying” items have been eliminated from the set.

Table 8. Results of regression analysis for auction 3

R = 0.72476122		R <sup>2</sup> = 0.52527883		Corrected R <sup>2</sup> = 0.45934533		
F(10.72) = 7.9668		p < 0.00000		Standard error of estimate = 12 087		
	Beta	Standard error beta	B	Standard error B	T	P
A	<b>0.537635</b>	<b>0.076281</b>	<b>14794.6</b>	<b>2099.10</b>	<b>7.048069</b>	<b>0.000000</b>
T	<b>-0.212461</b>	<b>0.082648</b>	<b>-105.3</b>	<b>40.97</b>	<b>-257067</b>	<b>0.012311</b>
F	<b>0.303712</b>	<b>0.087860</b>	<b>0.9</b>	<b>0.3</b>	<b>3.45676</b>	<b>0.000921</b>
Th A	0.146049	0.113814	4587.9	3575.28	1.283222	0.201697
Th B	0.171401	0.125637	7872.6	5770.58	1.364260	0.174773
Th C	0.069646	0.101351	4965.9	7226.55	0.687182	0.493156
T A	<b>0.252623</b>	<b>0.096483</b>	<b>10476.7</b>	<b>4001.32</b>	<b>2.618302</b>	<b>0.009839</b>
T B	<b>0.179423</b>	<b>0.081888</b>	<b>8340.6</b>	<b>3806.61</b>	<b>2.191088</b>	<b>0.030256</b>
T C	<b>0.233399</b>	<b>0.094223</b>	<b>6210.0</b>	<b>2506.98</b>	<b>2.477083</b>	<b>0.014530</b>
S	0.105318	0.078957	9124.1	6840.31	1.333871	0.184509

A – author; T – time of origin; F – format; Th – theme; t – technique; S – signature.

Source: author’s own research in Statistica programme

Table 9. Comparison of the results of multiple regression for selected samples (auctions)

		Auction 1	Auction 2	Auction 3
Determination coefficient R <sup>2</sup>		0.518325 45	0.52590105	0.52527883
Corrected R <sup>2</sup>		0.476073 30	0.45912656	0.45934533
Standardized beta* coefficients	Author	<b>0.513543</b>	<b>0.435939</b>	<b>0.537635</b>
	Time of origin	- <b>0.203397</b>	<b>-0.206544</b>	<b>-0.212461</b>
	Format	<b>0.373791</b>	<b>0.331840</b>	<b>0.303712</b>
	Theme A	0.029657	0.06444	0.146049
	Theme B	0.036288	0.15618	0.171401
	Theme C	0.032992	0.10241	0.069646
	Technique A	<b>0.321562</b>	<b>0.316977</b>	<b>0.252623</b>
	Technique B	<b>0.293101</b>	<b>0.227359</b>	<b>0.179423</b>
	Technique C	<b>0.303142</b>	<b>0.281960</b>	<b>0.233399</b>
Signature	0.067547	0.127159	0.105318	

\*Statistically significant standardized beta coefficients are presented in bold type

Source: author’s own research in Statistica programme

The presentation of the results of the analysis (Table 9) leads to the number of conclusions. The assessment of matching the regression function with empirical data was done on the basis of the multiple correlation coefficient, the determination coefficient, and the corrected determination coefficient.<sup>6</sup> It should be noted that the different cases of matching models with the empirical data from different auctions are similar

<sup>6</sup> Multiple correlation coefficient R assumes values from [0,1], and makes it possible to determine the correlation between the dependent variable and non-dependent variables treated as a whole. Determination coefficient R<sup>2</sup> specifies the extent to which the observed changeability of the dependent variable in the sample is accounted for by regression with regard to all the non-dependent variables simultaneously. Corrected determination coefficient R<sup>2</sup> assesses the model’s matching with general population.

in terms of quality. The obtained regression models justify 40%-50% of the changeability of auction prices.

At the same time, in terms of the statistical significance of regression function parameters, theme- and signature-related parameters turn out to be insignificant unlike those related to the format, time of origin and applied technique. A direct comparison of the correlations between the particular independent variables and the dependent variable may be based on standardized beta coefficients.<sup>7</sup> They may constitute a basis for determining the order of significance of the factors which affect the auction prices of the pieces of art: author, format, time of origin, applied technique. The negative sign of beta for the time of origin indicates a negative relation between the time of origin and the auction price – older pieces of art are sold at higher prices on the auction market.

It should be noted that following the elimination of insignificant variables, the assessment of the parameters for the remaining variables does not change considerably. It is also true of the determination coefficients for the obtained models (Table 10).

Table 10. The degree of matching multiple regression models for selected samples (auctions)

Measures	Auction 1	Auction 2	Auction 3
Determination coefficient R <sup>2</sup>	0.51375417	0.50204729	0.51067434
Corrected R <sup>2</sup>	0.48902981	0.45429840	0.45312478

The insignificant variables have been removed from the model.

Source: author’s own research in Statistica programme

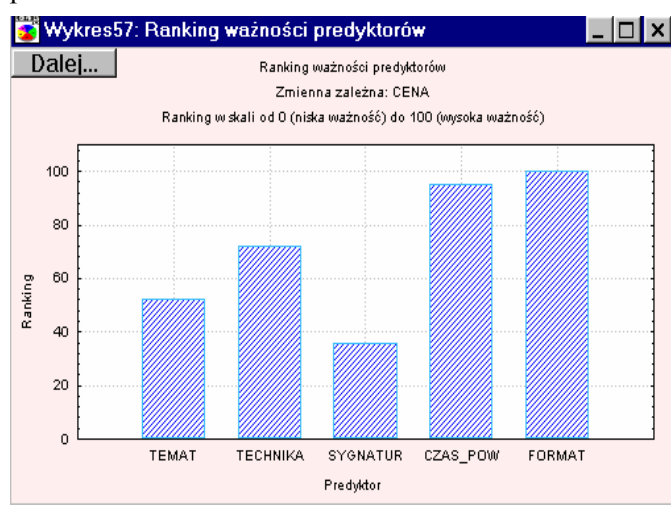
On the basis of the results obtained in the course of the regression analysis it may be concluded that there is a linear correlation between such qualities of a piece of art as the author, format, time of origin, applied technique and auction price levels. It should be stressed that attempts have been made to estimate the parameters of multiple regression models based on the assumption of a non-linear correlation between variables. However, they have not led to a higher degree of matching the obtained models.

<sup>7</sup> Coefficient beta indicates the extent to which standard deviation changes the value of the dependent value, if the value of the independent variable changes by one standard deviation with the remaining variables being at the same level.

#### 4 Classification trees used for identification of art prices' determinants

Non-parametric method CART (*Classification and Regression Trees*) has also been applied in the analysis to set the significance of auction price predictors<sup>8</sup>. Assuming different criteria and distribution rules (Gini, chi-square, G-square), a set of classification trees has been established. Then, choosing a tree with the largest number of end knots and the lowest re-substitution costs led to the most appropriate ranking of dependent variable predictors, ie the auction price of a piece of art. Fig. 3 presents the ranking of the significance of auction price predictors.

Fig. 3. Ranking of the significance of art auction price predictors



Source: author's own research based on statistical programme STATISTICA

Considering the set of variables describing the features of a piece of art, the following ranking of auction price predictors has been established (within the range of variables included in the model):

1. format,
2. time of origin,
3. applied technique,
4. theme,
5. signature.

However, according to ANOVA and multiple regression results theme and signature are not important statistically.

#### 5 Conclusions

The paper presents the analysis of the impact of several features of a piece of art (author, format, time of origin, technique, theme, and signature) on auction prices. The identification of relations is based on variance analysis, multiple regression analysis and classification trees. In the light of the obtained results it should be stated that the applied statistical methods lead to similar results. The relations between such factors as author, format, time of origin and applied technique is statistically significant, while the impact of theme and signature is insignificant. On the basis of the set of significant variables, the following ranking of auction price predictors has been determined: author, format, time of origin and applied techniques.

The results presented in this paper constitute part of research studies on the identification of factors affecting auction prices of the works of art. The features which describe the pieces of art belong to one category of factors affecting their price. The determinants of art prices can also be connected with sellers, with buyers, with auctioneer, with market circumstances and art market environment. These relations (between other factors and art prices levels) will be discussed in the author's further analyses.

<sup>8</sup> Method CART has a number of advantages: it makes use of all combinations of continuous and categorical variables; it is not sensitive to untypical observations; it may be effectively applied for the sets of data in which non-dependent variable data are missing.

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