Criteria of Database Quality Appraisement and Choice Stochastic Models in Prediction of Real Estate Market Value

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Key words: cadastre, real estate, valuation, property taxes, market value

SUMMARY

Databases of real estates, analysed in consideration of the coherence, are the ground for estimation of evaluation model in linear form (or non-linear, reducible to the linear model) of multiple regression. Covariance matrix for predicted values of real estates determining the regression model is the basis for calculation of defined parameters that are matrix transformation invariants. On the basis of these parameters, choice rules of the optimum evaluation model for real estate market value prediction can be formulated.

Three following parameters are proposed for market information analysis:

- coefficient of determination R^2, i.e. standard measure of reliance in estimated evaluation model: $$R^2 = 1 - \frac{\det K}{\det K_0},$$
- parameter determined from trace of covariance matrix:
  - $$\sigma_{tr} = \frac{1}{W_{śr}} \sqrt{\frac{tr\{Cov(W)\}}{n}},$$
- parameter determined from determinant of covariance matrix:
  - $$\sigma_{det} = \frac{1}{W_{śr}} \sqrt[u^2]{det\{Cov(W)\}},$$

where:

K	correlation matrix, including complete correlation coefficients between all pairs of variables (r_{ij}),
det K	determinant of correlation matrix,
det K0	determinant of sub-matrix, created by eliminating the first verse and the first column in matrix K, i.e. correlation coefficients concerning depending variable (price)
$tr\{Cov(W)$	trace of covariance matrix for predictions market values of real estates setting evaluation model,
$det\{Cov(W)\}$	determinant of covariance matrix for predictions market values of real estates setting evaluation model,
$W_{śr}$	average value of predictions market values of real estates setting evaluation model,
n	number of real estates used for models estimation.
u	number of independent variables appearing in model.

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1. INTRODUCTION

Evaluation of real estates became last time a very important and indispensable element of real estates management. Consequently, new, improved methods of estimation are needed. On the basis of real estate assessment regulations, there are many ways of applying statistical methods and of creating multidimensional mathematical models, which describe as well as possible a given market of real estates. Multidimensional character of the problem results from the multitude of factors influencing directly the real estate value. Creation of mathematical model for a chosen market is a problem extremely complex, because it involves an appropriate preparation of modelling database as regards its completeness and reliability, taking into consideration an optimum selection of variables. To find the "best" model, it is necessary to examine a great amount of information in database. Therefore, it is necessary to formulate some criteria of choosing an optimal model, as well as the criteria allowing the estimation of the quality of modelling database form. It concerns mostly relation between the quantity of variables and the base size.

The methodology in this field develops dynamically. There are many suggestions, in literature and in practical assessments, of applying different formulas or even total mathematical models. This is the reason to formulate criteria of choosing a model optimum on a given market for evaluation of real estates. The author proposes the selection of such a model according to the previously determined invariant parameters. On the ground of these parameters values, for a database including real estates of a given local market, selection criteria allowing to choose an optimal model of pricing and estimating database quality can be formulated.

The reason to undertake such a task is the necessity of doing a general valuation of real estates in Poland. In accordance with Art. 162 of the law concerning management of real estates, the cadastral value must take into consideration the differences between attributes of particular real estates and it should approximate their market value. The cadastral value is used to determine the basis of taxation of a real estate and in case of official activities when realisation is based on the market value of a real estate.

2. DEFINITIONS OF INVARIANT PARAMETERS

Three following parameters are suggested for an analysis of market information:

– coefficient of determination R^2, i.e. standard confidence measure of estimated model of pricing:

$$R^2 = 1 - \frac{\det K}{\det K_0}, \tag{1}$$

where:

$$K = \begin{Bmatrix} 1 & r_{01} & r_{02} & \dots & r_{0k} \\ r_{10} & 1 & r_{12} & \dots & r_{1k} \\ r_{20} & r_{21} & 1 & \dots & r_{2k} \\ \dots & \dots & \dots & \dots & \dots \\ r_{k0} & r_{k1} & r_{k2} & \dots & 1 \end{Bmatrix} \tag{2}$$

K correlation matrix, including coefficients of total correlation within each pair of variables (r_{ij}),

det *K* determinant of correlation matrix,

det K_0 determinant of submatrix, created by cancelling of the first row vector and the first column in matrix K, i.e. correlation coefficients concerning dependent variable (price).

R coefficient of linear multiple correlation, determining the degree of matching the hyperplane to the point pattern representing prices and attributes of individual real estates.

$1-R^2$ is a coefficient of non-conformance of the model and the real estates market values used for estimation of a pricing model.

– parameter settled on the basis of covariance matrix trace, determined by formula:

$$\sigma_{tr} = \frac{1}{W_{śr}} \sqrt{\frac{tr\{Cov\{W\}\}}{n}}, \tag{3}$$

where:

$tr\{Cov(W)\}$ trace of covariance matrix for predicted market values of real estates establishing a pricing model,

$W_{śr}$ mean value of predicted real estates market values establishing

n number of real estates used to estimate a model.

– parameter calculated from the covariance matrix determinant, determined by formula:

$$\sigma_{det} = \frac{1}{W_{śr}} \sqrt[u^2]{det\{Cov(W)\}}, \tag{4}$$

where:

$det\{Cov(W)$ determinant of covariance matrix for predicted market values of real estates establishing a pricing model,

$W_{śr}$ mean value of predicted real estates market values establishing a pricing model,

u number of independent variables occurring in a model.

The analysis of formulas (3) and (4) indicates that these quantities constitute some kind of measure of dispersion round the mean model value, so they can be objective parameters applied to formulate criteria of reliability of databases used in modelling of market value.

3. METHODOLOGY OF INVESTIGATION

Information on land properties for housing as the object of commercial traffic was used as starting material for investigation. It comes from 10 different local markets of properties. Great differences of prices and variable dynamics of transactions are characteristic features of analysed markets. Gathered databases contain 20 to 130 properties. Information includes totally 530 land properties.

The market of estates is created for every town (commune) separately. For big towns, separate estate markets are created for particular quarters. It is caused by difficulty to find attributes (variables) easily identifiable and measurable, which could be used to transform prices to one common market of properties. In majority of cases, properties prices are positively different, even in communes of similar number of inhabitants. Factors like: labour market, attractiveness of a town, environment purity, economic prospects, situation, landscape, are decisive in pricing. We can notice also different reactions to local factors, visible in characteristics of verified models.

Achieved data have been subject of a pre-treatment aiming to prepare pricing models to the tests. Preliminary analyses permitted to define methods of grouping achieved data, isolated features influencing estate value and imagined influence rate of respective features. By this treatment, databases are brought to connectivity allowing to acquire more reliable results of investigation.

In modelling process of real estates market, first, in every database, a multidimensional linear model as linear multiple regression has been tested:

$$F(X_i, a) = w_i = a_0 + \sum_{k=1}^{u} X_{ik} * a_k \qquad (5)$$

where:

- w_i model value of i-th estate in a given database,
- X_i attributes value vector for i-th estate (1xu),
- X_{ik} value of attribute k for i-th estate,
- a_0 free term in the model,
- a vector of multiple regression coefficient ((u+1)x1),
- a_k coefficient of regression standing by attribute k.

If the analysed market of real estates was steady, variability of prices in relation to respective attributes would be linear. However, the market of real estates in Poland being not stable, variability of prices often is not linear and sometimes changes are even abrupt. Consequently, in cases where linear model proved unreliable, estimation of linear model parameters has been done, proceeding as follows:

- For each attribute and each unit price, a function in form general is defined:

  $$Y = g(X_k), \tag{6}$$

  where:

  X_k variable representing the value of the attribute k,

  Y prices of real estates in database.

  The function g may have very different forms. The following elementary functions have been considered: linear, polynomial, power, logarithmic, exponential, irrational.

  In mathematical statistics, there is no analytical method enabling an optimal selection of a suitable form of function. Reliability measure for regression model (6), describing variability of market prices in relation to the established attribute, is the square of the curvilinear correlation coefficient q:

  $$q^2 = 1 - \frac{\sum_{i=1}^{n}[y_i - g(X_k)]^2}{\sum_{i=1}^{n}[y_i - \hat{y}]^2} \tag{7}$$

  where:

  y_i unit price of i-th estate in database,

  $\hat{y}$ mean value (arithmetic mean) of estate price from a database,

  $g(X_k)$ predicted unit price for attribute k of a real estate, resulting from admitted non-linear pricing model.

  This coefficient value may be a criterion for selecting suitable form of function g.

- Selected forms of function g were used to create multidimensional models, i.e. global non-linear functions F for respective databases:

  $$W = F(X, a) \tag{8}$$

  where:

  W set of predicted prices generating a pricing model,

  X multidimensional variable representing real estate attributes,

  a vector of model parameters.

  Respective functions g for different attributes were – within function F – interrelated by a dependence additive or multiplicative.

  Parameters of all analysed regression models were estimated with least squares method.

- Each of estimated non-linear models has been reduced to a linear model (5) with the assistance of Taylor series expansion.

Reliability of estimated models has been verified by testing the hypothesis on variance equality of the part explained by regression model and of the part unexplained. Fisher-Snedecor test has been used here, at the significance level p = 0,05, for which test statistics has the following form:

$$F = \frac{R^2}{1-R^2} * \frac{n-m}{m-1} \qquad (9)$$

where:

R	coefficient of multiple linear correlation,
n	size of trial (quantity of real estates in a database),
u	quantity of independent variables in a model,
$m = u + 1$	quantity of estimated parameters of a pricing model.

The above test not only examines the absolute variance ration of explained and unexplained parts, but also takes into account the necessity to retain in a model right proportions between the quantity of cases and the quantity of unknowns. In consequence, some (9) models have been eliminated, even from among these having a very high (above 0,90) absolute value of R^2.

4. DETERMINATION OF INVARIANTS VALUES

The last step was the determination of values of previously defined invariant parameters (1,3,4). Covariance matrix for model values of estates has been determined as follows:

$$Cov(W) = \hat{\sigma}_0^2 \cdot X^T (X^T X)^{-1} X \qquad (10)$$

where:

$\hat{\sigma}_0^2$ unloaded estimator of remainder variance (determining inaccuracy of model parameters estimation):

$$\hat{\sigma}_0^2 = \frac{Y^T Y - \hat{a}^T X^T Y}{n-u-1} \qquad (11)$$

$X = \begin{bmatrix} 1 & x_{11} & \cdots & x_{1u} \\ 1 & x_{21} & \cdots & x_{2u} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & \cdots & x_{nu} \end{bmatrix}$ matrix containing numbers ‘1’ and independent variables (attributes),

$a = \begin{bmatrix} a_0 \\ a_1 \\ \vdots \\ a_u \end{bmatrix}$ vector of multiple linear regression coefficients,

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}$$ vector of dependent random variable (prices of estates).

In sum, on all estates databases, many different models determining estate market value have been tested. First, all models with multiple correlation coefficient less than 0,60 have been eliminated. For each of remaining 97 models, after the correlation matrix for variables occurring in model and covariance matrix for estate model values establishing a pricing model have been determined, the values of three defined invariants were calculated. Thereby, 97 sets of these three numbers, were achieved. The results are presented in Table 1. Besides the values of invariants, the table contains: the name of the town where the data used to modelling were acquired, the type of model and constant values describing the database and the model. They are:

- number of real estates in a database – *n*,
- number of independent variables in a model – *u*,
- number of estimated parameters in a pricing model – *m*,
- number of degrees of freedom – $k = n - m$,
- remainder variance - σ_0^2.

Table 1; Values of Invariants

Nr	MIEJSCOWOŚĆ	ZMIENNOŚĆ	MODEL	*n*	*u*	*m*	*k*	σ_0^2	R^2	σ_{tr}	σ_{det}
1	**Bolesław**	**Liniowa**	**1**	**18**	**13**	**14**	**4**	**2,807**	**,936**	**,166**	**,05308**
2	Bolesław	Liniowa	2	18	7	8	10	5,206	,702	,172	,00009
3	**Bolesław**	**Liniowa**	**3**	**18**	**8**	**9**	**9**	**5,364**	**,723**	**,183**	**,00108**
4	**Bolesław**	**Liniowa**	**4**	**18**	**9**	**10**	**8**	**5,930**	**,728**	**,203**	**,00466**
5	**Bolesław**	**Liniowa**	**5**	**18**	**10**	**11**	**7**	**4,643**	**,814**	**,189**	**,01180**
6	**Bolesław**	**Liniowa**	**6**	**18**	**11**	**12**	**6**	**4,762**	**,836**	**,201**	**,02372**
7	**Bolesław**	**Liniowa**	**7**	**18**	**12**	**13**	**5**	**4,750**	**,864**	**,212**	**,03821**
8	Bolesław	Liniowa	K-P-D-M	18	4	5	13	4,286	,681	,120	,00000
9	Bolesław	nieliniowa	14	18	10	11	7	2,632	,894	,148	,00983
10	Bolesław	nieliniowa	41	18	14	12	3	,325	,994	,057	,05616
11	**Bolesław**	**nieliniowa**	**42**	**18**	**14**	**17**	**3**	**,325**	**,994**	**,057**	**,05586**
12	Bolesław	nieliniowa	43	18	12	15	5	,355	,990	,052	,02546
13	Bolesław	nieliniowa	44	18	12	15	5	,262	,992	,047	,02530
14	Bolesław	nieliniowa	45	18	13	16	4	,266	,994	,050	,03963
15	Bolesław	nieliniowa	46	18	11	14	6	,708	,976	,076	,01648
16	Bolesław	nieliniowa	47	18	10	13	7	,834	,966	,080	,00804
17	Bolesław	nieliniowa	48	18	5	6	12	3,365	,768	,114	,00000
18	Bolesław	nieliniowa	49	18	5	8	12	3,365	,768	,114	,00000
19	Bolesław	nieliniowa	50	18	6	7	11	3,178	,800	,123	,00000

Nr	MIEJSCOWOŚĆ	ZMIENNOŚĆ	MODEL	*n*	*u*	*m*	*k*	σ_0^2	R^2	σ_{tr}	σ_{det}
20	Bolesław	nieliniowa	51	18	8	9	9	3,064	,842	,138	,00000
21	Bolesław	nieliniowa	52	18	10	10	7	1,654	,934	,111	,00000
22	Bolesław	nieliniowa	53	18	8	11	9	,986	,949	,077	,00054
23	Bolesław	nieliniowa	54	18	9	12	8	,784	,964	,072	,00248
24	Bolesław	nieliniowa	55	18	8	11	9	,715	,963	,065	,00049
25	Busko Zdrój	liniowa	1	31	15	16	15	37,875	,810	,090	,00297
26	Busko Zdrój	liniowa	2	31	13	14	17	38,515	,781	,084	,00098
27	Busko Zdrój	nieliniowa	2a	31	17	18	13	13,227	,942	,057	,00535
28	Busko Zdrój	nieliniowa	2b	31	17	19	13	11,151	,952	,052	,00522
29	Busko Zdrój	nieliniowa	3a	31	16	18	14	10,436	,951	,049	,00373
30	Busko Zdrój	nieliniowa	4a	31	18	20	12	9,954	,960	,051	,00672
31	Busko Zdrój	nieliniowa	4b	31	18	19	12	11,193	,955	,054	,00682
32	Busko Zdrój	nieliniowa	5a	31	16	18	14	9,116	,957	,046	,00371
33	Busko Zdrój	nieliniowa	5b	31	16	17	14	10,108	,953	,048	,00377
34	Busko Zdrój	nieliniowa	6	31	15	16	15	10,212	,949	,047	,00250
35	Krowodrza	nieliniowa	1a	38	13	14	24	2324,053	,695	,342	,00033
36	Krowodrza II	liniowa	1	131	12	13	118	779,711	,919	,040	,00000
37	Krowodrza II	liniowa	2	127	12	13	114	469,446	,949	,032	,00000
38	Krowodrza II	nieliniowa	1	131	16	17	114	804,668	,920	,047	,00000
39	Krowodrza II	nieliniowa	1a	127	16	17	110	473,673	,951	,037	,00000
40	Krowodrza II	nieliniowa	1b	121	16	17	104	343,562	,962	,033	,00000
41	Nowy Sącz	liniowa	1	30	13	14	16	23,934	,811	,147	,00229
42	Nowy Sącz	liniowa	2	30	12	13	17	23,438	,803	,140	,00104
43	Nowy Sącz	liniowa	3	29	13	14	15	15,782	,879	,120	,00255
44	Nowy Sącz	liniowa	4	29	12	13	16	15,086	,877	,112	,00118
45	Nowy Sącz	liniowa	5	28	12	13	15	11,458	,898	,105	,00146
46	Nowy Sącz	liniowa	6	28	11	12	16	10,983	,895	,098	,00055
47	Nowy Sącz	nieliniowa	2	30	16	17	13	21,975	,859	,150	,00949
48	Nowy Sącz	nieliniowa	3	30	16	17	13	21,942	,859	,151	,00946
49	Proszowice	liniowa	1	63	9	10	53	27,468	,894	,191	,00014
50	Proszowice	liniowa	2	60	9	10	50	18,913	,923	,197	,00247
51	Proszowice	nieliniowa	1	57	10	12	46	8,016	,964	,112	,00000
52	Proszowice	nieliniowa	2	57	10	12	46	8,016	,964	,112	,00000
53	Proszowice	nieliniowa	4	57	9	11	47	9,610	,963	,114	,00000
54	Proszowice	nieliniowa	5	57	9	10	47	9,648	,963	,115	,00000
55	Proszowice	nieliniowa	5'	54	9	10	44	5,284	,975	,116	,00000
56	Proszowice	nieliniowa	5a	57	8	9	48	9,690	,962	,115	,00000
57	Proszowice	nieliniowa	5'a	54	8	9	45	5,296	,975	,115	,00000
58	Proszowice	nieliniowa	5b	44	8	9	35	,463	,998	,046	,00000
59	Proszowice	nieliniowa	6	57	8	10	48	9,560	,963	,121	,00000
60	**Przeworsk**	**liniowa**	**1**	**30**	**15**	**16**	**14**	**1,006**	**,605**	**,033**	**,00491**
61	**Przeworsk**	**nieliniowa**	**1**	**30**	**18**	**19**	**11**	**1,158**	**,643**	**,038**	**,01357**

Nr	MIEJSCOWOŚĆ	ZMIENNOŚĆ	MODEL	*n*	*u*	*m*	*k*	σ_0^2	R^2	σ_{tr}	σ_{det}
62	Rzeszów	liniowa	1	48	13	14	34	33,689	,824	,060	,00004
63	Rzeszów	liniowa	2	47	13	14	33	25,821	,856	,052	,00004
64	Rzeszów	liniowa	3	46	13	14	32	21,845	,875	,048	,00049
65	Rzeszów	nieliniowa	1	48	13	14	34	34,447	,820	,061	,00004
66	Rzeszów	nieliniowa	1a	47	13	14	33	26,610	,852	,053	,00004
67	Rzeszów	nieliniowa	1b	46	13	14	32	22,785	,870	,049	,00005
68	Rzeszów	nieliniowa	2	48	13	14	34	33,637	,824	,060	,00004
69	Rzeszów	nieliniowa	2a	47	13	14	33	26,123	,854	,052	,00005
70	Rzeszów	nieliniowa	2b	46	13	14	32	22,500	,871	,048	,00005
71	Rzeszów	nieliniowa	3	48	13	14	34	33,522	,825	,060	,00000
72	Rzeszów	nieliniowa	3a	47	13	14	33	25,904	,856	,052	,00004
73	Rzeszów	nieliniowa	3b	46	13	14	32	22,196	,873	,048	,00005
74	Rzeszów	nieliniowa	4	48	13	14	34	33,640	,824	,059	,00040
75	Rzeszów	nieliniowa	4a	47	13	14	33	25,669	,857	,051	,00004
76	Rzeszów	nieliniowa	4b	46	13	14	32	21,648	,876	,047	,00005
77	Świdnik	liniowa	2	42	11	12	30	30,296	,615	,094	,00001
78	Świdnik	liniowa	3	41	11	12	29	25,487	,676	,088	,00002
79	Świdnik	liniowa	4	41	7	8	33	27,622	,600	,073	,00000
80	Świdnik	liniowa	5	40	7	8	32	24,308	,652	,069	,00000
81	Świdnik	liniowa	6	40	10	11	29	22,262	,711	,079	,00000
82	Świdnik	liniowa	7	40	9	10	30	21,527	,711	,074	,00000
83	Świdnik	nieliniowa	2	41	13	14	27	25,092	,640	,093	,00023
84	Świdnik	nieliniowa	3	40	13	14	26	21,775	,736	,089	,00028
85	Świdnik	nieliniowa	4	41	13	14	27	24,974	,704	,093	,00023
86	Świdnik	nieliniowa	5	40	13	14	26	20,615	,760	,085	,00027
87	Świdnik	nieliniowa	7	40	14	15	25	16,437	,816	,080	,00060
88	Świdnik	nieliniowa	I	40	16	17	23	15,671	,839	,083	,00205
89	Świdnik	nieliniowa	II	40	15	16	24	15,515	,833	,079	,00118
90	Świdnik	nieliniowa	III	39	15	16	23	15,671	,834	,081	,00139
91	Świdnik	nieliniowa	IV	39	14	15	24	15,515	,829	,078	,00071
92	Trzyciąż	liniowa	1	50	13	14	36	1,864	,743	,063	,00005
93	Trzyciąż	nieliniowa	1	50	18	19	31	1,192	,859	,058	,00291
94	Trzyciąż	nieliniowa	2	49	18	19	30	,853	,898	,049	,00311
95	Trzyciąż	nieliniowa	3	48	18	19	29	,580	,928	,041	,00331
96	Trzyciąż	nieliniowa	4	50	14	15	35	1,289	,828	,053	,00015
97	Trzyciąż	nieliniowa	5	46	14	15	31	,523	,934	,035	,00025

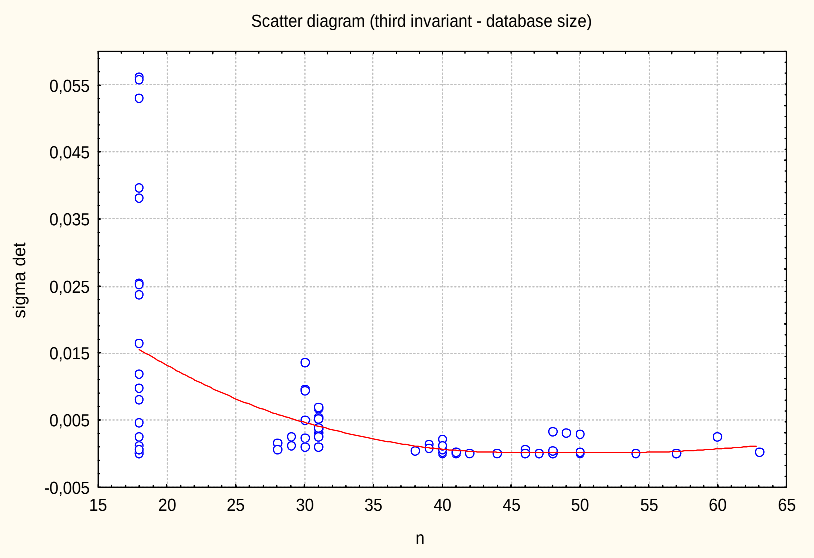
5. STUDY ON DEPENDENCE OF INVARIANTS ON QUANTITIES DESCRIBING THE DATABASE OF REAL ESTATES AND THE PRICING MODEL

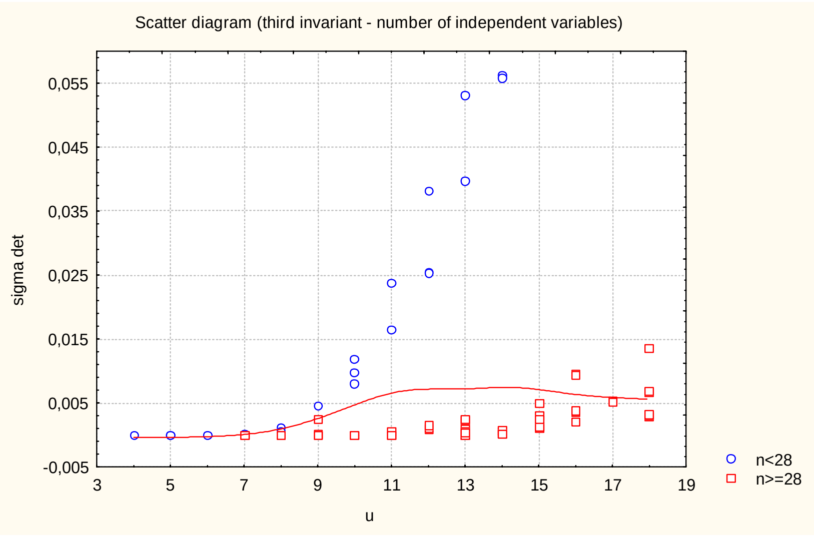
In order to formulate criteria for real estates database and model reliability estimation, several scatter diagrams of invariants dependence on constant quantities describing a database and applied pricing model. On each of these diagrams, a trend line, estimated with least squares method, has been put on. It enables to confirm the occurrence or non-occurrence of any relations between these quantities and, in consequence, to draw conclusions concerning the model or the database.

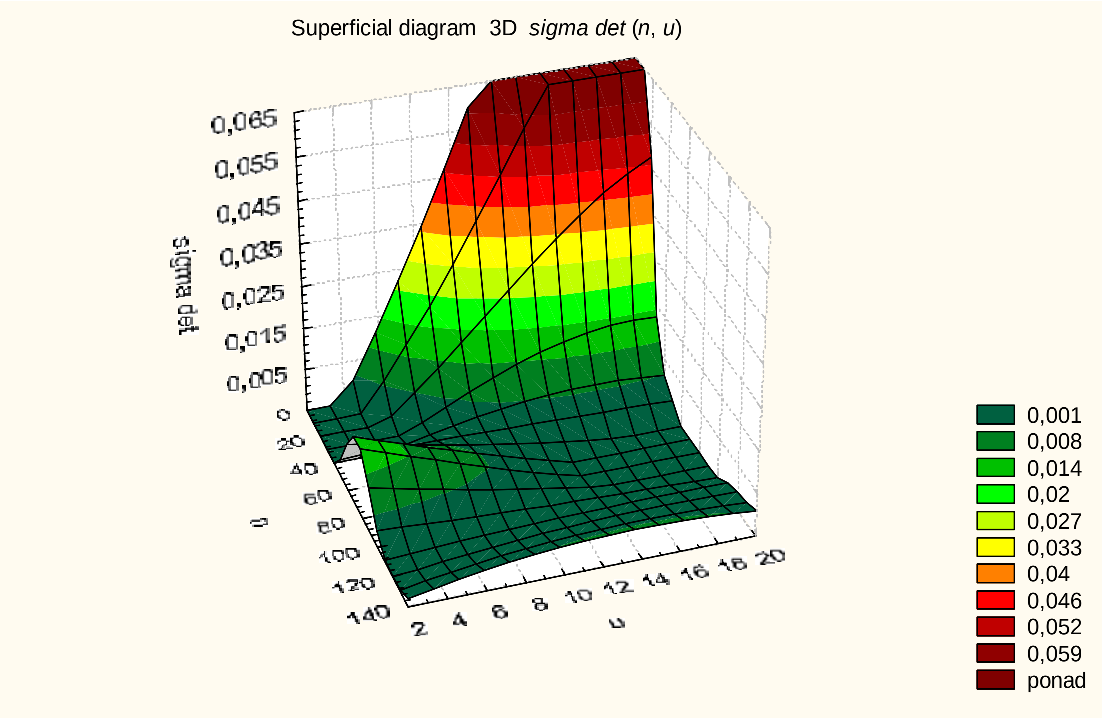
Diagrams of invariants dependence on following parameters have been made:

- database size,
- number of independent variables in a model,
- number of degrees of freedom,
- remainder variance.

Selected diagrams of the whole set are presented below:







6. CONCLUSIONS

The main purpose of the study was the presentation of possibilities for valuation of a database and a model applied to estimate the real estate market value, using defined covariance matrix transformation parameters – invariants for model values of estates. After the parameters of about a hundred models, tested on 10 databases of different size (18 to 132 estates) and of different amount of features taken into account (4 to 18), have been estimated, and after the values of three invariants: R^2, σ_{tr}, σ_{det} – have been determined, on the basis of these invariants scatter diagrams in conjunction with characteristics of databases and models, the following conclusions can be formulated:

- Optimal quantity of real estates in a database for modelling the estates values should correspond to threefold number of determined parameters of a pricing model. It must be pointed that this number should be, at least, twice as large as the number of determined model parameters, and that its enlarging (more than quadruple number of parameters) in most cases does not bring improvement of the model.
- Maximum number of independent variables should not exceed 14 parameters. Optimum number of parameters (attributes) should be determined by the preliminary analysis of real estates market.
- The number of degrees of freedom in a pricing model should be contained between 28 and 42.
- The selection of a database for estimation of a pricing model can be acknowledged to be optimal if the value of invariant σ_{det} is situated in the interval: $\sigma_{det} \in (0{,}0008; 0{,}0055)$.

- The selection of model for estimation of real estates values can be acknowledged as satisfying when the value of determination coefficient R^2 fulfils the inequality: $R^2 \geq 0{,}837$.
- Using the parameter σ_{tr} , criteria of selecting a database for estimation of a pricing model can not be formulated, because the value of this parameter shows a strong fluctuation.
- From the comparison of conclusions 4 and 6 it may be observed that for selection of a correct pricing model, consideration of nothing but variances of model values is not sufficient. It is necessary to take into account the whole covariance matrix for model values *Cov*(*W*).

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