The Hedonic Econometric Model and Sourcing Management of the Cadastral Value of Land

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***Abstract*— The authors identified and evaluated the key hedonic factors of cadastral value of land for individual housing construction. In order to identify the observed factors determining the value of land plots, linear, power and exponential specifications of the regression hedonic model of cadastral value based on data on 160 land plots in the city were constructed based on the source management. Zelenodolsk in 2019. The empirical estimates of the specifications presented in the article confirmed the hypothesis about the influence of the distance to the region capital of the Russian Federation, the distance to the railway, the distance to the nearest recreational zone, the distance to the nearest water body, the land area on its cadastral value. The greatest impact on the cadastral value of land plots is the distance to the capital of the Russian Federation and the land area. The influence of the coefficient of the length of the land plot on its cadastral value in all built specifications was not confirmed. The quality of the results was tested using Fisher test, student test, regression equation specification error test (RESET), testing of regression residues on heteroskedasticity and autocorrelation (White test, Breusch-Pagan test). The results of the empirical estimates confirmed the feasibility of the practical use of this approach to the assessment of the cadastral value of land.**

***Keywords*—** *hedonic model, cadastral value, source management, housing, regression, least squares method.*

1. Introduction

Determination of the cadastral value of the land plot involves the calculation of the most likely price at which it can be purchased, based on the possibility of continuing the actual type of its use, regardless of restrictions on the disposal of them. In this study a comparative approach is used to assessing the value of the land to determine the cadastral value, which is based on a comparison of the prices of transactions (proposals) for similar real estate. The coefficients in the hedonic model show the implicit price of each of the characteristics, that is, the value of each characteristic in the total value of the land. Based on the content of the comparative approach, the model predicted (calculated) values of the dependent variable, in our opinion, can be interpreted as values of the cadastral value of land plots. Then the positive difference between the actual values of the market value and the predicted (calculated) values of the dependent variable is the excess of the market value over the cadastral value. In case of a negative difference between the actual values of market value and the predicted (calculated) values of the dependent variable, the market value is cadastral.

The first applications of the hedonic model to the analysis of prices were made in [1-3]. In [4-6] different functional forms of hedonic regression were compared in the problems of variation of office rent prices. As a rule, authors of works on commercial real estate [5-10] get similar results on the impact of the characteristics of the office on the price. Residential real estate was subjected to a closer analysis of researchers due to both social significance and data availability [11-20, 21-27]. There is practically no econometric analysis of the land market in Russian scientific practice. In the present work we use the extended composition of hedonic characteristics, evaluate a number of alternative specifications, considering the characteristics of the conditions of the transaction. Understanding the functioning of the land market is of fundamental importance both for developers and for the authorities making decisions on the development and expansion of the city and interested in increasing economic activity in the city. Therefore, the purpose of this work is to build a hedonic model of cadastral value of land for housing construction with a set of variables that can take into account the effects of improvements in land quality in Zelenodolsk, which is in close proximity to the metropolis of the Volga region, Kazan. This small town is interesting because it includes a more favorable compared to the metropolis living conditions and good transport routes for pendulum migration for the purpose of earnings. Our methodology of cadastral value assessment, based on the recommendations of the Order of the Ministry of economic development of the Russian Federation of 12.05.2017 N 226

(version of 09.08.2018) "On approval of methodical instructions on state cadastral valuation", allows more accurate measurement of cadastral value through the use of several alternative specifications and an expanded composition of hedonic characteristics [28, 29].

2. Methods

Given these Guidelines and the nonlinear nature of most dependencies in large spatial markets, linear, multiplicative power and exponential regression specifications of the hedonic model of cadastral value are used.

Formally, the linear specification of the hedonic model of the cadastral value of land has the following form :

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \varepsilon$$

The multiplicative power-law specification of the cadastral value of land hedonic model has thefollowing form:

$$Y = \beta_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} X_7^{\beta_7} \varepsilon$$

After linearization, it turns out to be the following:

$$\ln Y = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \ln \varepsilon$$

The exponential specification of the hedonic model of the cadastral value of land has the form:

$$Y = \beta_0 e^{\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7} \cdot \varepsilon$$

After linearization, it takes the form:

$$\ln Y = \ln \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \ln \varepsilon$$

Based on the study [16] in the field of assessing the hedonic value of land for individual housing construction, we use factors that can have an impact on the cadastral value of land (Y) [30].

A sample of 160 land plots in Zelenodolsk was formed. The necessary information about the pricing factors in the framework of the study was obtained using the electronic information geolocation service "2GIS" (table.1).

Table 1. Descriptive statistics for the main variables used in hedonic cadastral value models

Variable	Number of observations	Average	Standard deviation	Minimum	Maximum
Factors characterizing the external environment of real estate					
X1 - Distance to the capital of the region of the Russian Federation (km)	160	18,99	0,88	17,30	20,73
X2 - Distance to the road (km)	160	0,10	0,09	0,01	0,47
X3 - Location relative to the railway (km)	160	0,71	0,53	0,05	2,17
Factors characterizing the immediate environment and the real estate market segment					
X4 - Location relative to the recreational area (km)	160	0,43	0,34	0,01	1,44
X5 - Location relative to the water body (km)	160	1,03	0,55	0,04	1,95
Factors that characterize a property					
X6 - The area of the land plot (sqm)	160	854,91	325,58	338	2040
X7 - The ratio of the length (running meter)	160	1,07	0,10	0,88	1,51

Source: authors ' calculations based on data of location-based service "2GIS" and website www.avito.ru

The estimation of the linearized model specifications is performed by the usual least squares method in the Gretl Software environment [17-23]. To verify the quality of the obtained models used the coefficient of determination, the average error of the approximation, the statistics of Fisher and student's t test and the RESET test for correct specification, test and white's test Brisa-Pagan to check the residues of the regression for heteroscedasticity.

3. Results and Discussion

The constructed specifications of the cadastral value of land plots hedonic model for the full set of variables are presented in Table 2.

Table 2. Results of hedonic regression assessment with a full set of price-forming factors

Regressors	Dependent variable (market value)		
	Linear model	Power-law model	Exponential model
Distance to the capital of the region of the Russian Federation (km)	246756***(30475,5)	3,73273***(0,404427)	0,157968***(0,0193307)
Distance to the road (km)	170316(296584)	0,0666685***(0,0189920)	0,336044* (0,188124)
Location relative to the railway (km)	259916***(50674,1)	0,115076***(0,0218932)	0,229512***(0,0321428)
Location relative to the recreational area (km)	−123949(76252)	−0,0523098***(0,0148648)	−0,0163780 (0,048367)
Location relative to the water body (km)	664144***(59504,4)	0,228299***(0,0230680)	0,549196*** (0,0377439)
The land plot area (sqm)	1286,77***(72,8097)	0,879733***(0,0468316)	0,000985458***(0,0000461835)
The ratio of the length (running meter)	3230,16(242151)	−0,0541160(0,200034)	−0,168210(0,153597)
Free ratio	−5,17355e+06*** (606287)	0,0786**(1,20604)	15515,5806*** (0,384570)
R^2	0,840024	0,880071963	0,848888133
Average approximation error, %	19,14	15,46	14,33
F-test (p-value)	3,36E-57	2,71E-61	4,02E-68
RESET-test (p-value)	2,59E-09	0,787	0,00589
White test	heteroskedasticity is present	heteroskedasticity is present	heteroskedasticity is present
Breusch-Pagan test	heteroskedasticity is present	heteroskedasticity is present	heteroskedasticity is present

Notes: standard errors are given in brackets; *** - coefficient is significant at 1% level; ** - coefficient is significant at 5% level; * - coefficient is significant at 10% level.
Source: calculations by the author according to the geolocation service "2GIS" and the site www.avito.ru

As can be seen from Table 2, the linear specification did not confirm the relationship of cadastral value with the distance to the road and to the recreational area. The exponential specification also did not confirm the relationship between the cadastral value and the distance to the recreational area. None of the specifications confirmed the connection between the cadastral value of the land plot and its length coefficient, which characterizes the shape of the land plot. To check the robustness of the study, the specifications of the hedonic model of the cadastral value of land plots were evaluated after the elimination of excess variables (Table. 3).

Table 3. Results of hedonic regression evaluation after elimination of excessive pricing factors

Regressors	Dependent variable (market value)		
	Linear model	Power-law model	Exponential model
Distance to the capital of the region of the Russian Federation (km)	243657*** (30299,0)	3,72737*** (0,402716)	0,153285*** (0,0193084)
Distance to the road (km)	-	0,0671066*** (0,0188654)	-
Location relative to the railway (km)	226203*** (45477,0)	0,116541*** (0,0211485)	0,219222*** (0,0289808)
Location relative to the recreational area (km)	-	−0,0524617*** (0,0148092)	-
Location relative to the water body (km)	704012*** (49298,0)	0,230289*** (0,0217974)	0,59197*** (0,0314157)
The land plot area (sqm)	1285,41*** (71,4112)	0,880598*** (0,0465805)	0,000973583*** (4,55076e-05)
The ratio of the length (running meter)	-	-	-
Free ratio	−5,16367e+06*** (537222)	0,079335** (1,20190)	14155,6625*** (0,342351)

R^2	0,836654	0,88022	0,838548003
Average approximation error, %	18,84	15,47	14,80
F-test (p-value)	6,83E-60	2,16E-62	9,43E-71
RESET-test (p-value)	8,36E-09	0,794	0,00153
White test	heteroskedasticity is present	heteroskedasticity is present	heteroskedasticity is present
Breusch-Pagan test	heteroskedasticity is present	heteroskedasticity is present	heteroskedasticity is present

Notes: standard errors are given in brackets; *** - coefficient is significant at 1% level; ** - coefficient is significant at 5% level; * - coefficient is significant at 10% level.
Source: calculations by the author according to the geolocation service "2GIS" and the site www.avito.ru

As can be seen from Table 3, this truncated set of variables explains a great share of variation (from 83.66% to 88.02%) of the dependent variable. The highest coefficient of determination has a power-law specification of the hedonic model of cadastral value (R2 = 0.8802). The smallest value of the average approximation error belongs to the exponential specification of the hedonic model of cadastral value, but the RESET test of Ramsey (Regression Equation Specification Error Test) confirms the correctness of the power specification at all possible levels of significance. The F-test for co-equality of coefficients to zero in regressors rejects the null hypothesis at all possible significance levels (P-value was 2.16 E-62). The value characteristics of land plots remaining in the power specification of the hedonic model of cadastral value are statistically significant.
The results of the White test and Breusch-Pagan test indicates heteroscedasticity of the regression residues in all specifications. Estimates of the more correct in comparison with other, power specification hedonic cadastral value model after the elimination of heteroskedasticity are presented in Table 4.

Table 4. Estimates of the power specification of the hedonic cadastral value model with correction for heteroskedasticity

Regressors	Dependent variable (market value)
	Power-law model
Distance to the capital of the region of the Russian Federation (km)	3,30975*** (0,220679)
Location relative to the railway (km)	0,0561263*** (0,0146344)
Location relative to the recreational area (km)	−0,0462422*** (0,00953664)
Location relative to the water body (km)	0,242657*** (0,0143441)
The land plot area (sqm)	0,908975*** (0,0250982)
Free ratio	0,1872951** (0,678141)
R^2	0,863749311
Average approximation error, %	16,58
F-test (p-value)	2,39E-89
RESET-test (p-value)	-
White test	no heteroskedasticity
Breusch-Pagan test	no heteroskedasticity

Notes: standard errors are given in brackets; *** - coefficient is significant at 1% level; ** - coefficient is significant at 5% level; * - coefficient is significant at 10% level.
Source: calculations by the author according to the geolocation service "2GIS" and the site www.avito.ru

The power specification of the hedonic model of cadastral value after elimination of excess variables and elimination of heteroskedasticity has the form:

$$Y = 0{,}1873 X_1^{3{,}3098} X_3^{0{,}0561} X_4^{-0{,}0462} X_5^{0{,}2427} X_6^{0{,}9089} \varepsilon$$

The resulting power specification of the hedonic model of cadastral value is applicable only for land with the type of permitted use of "Individual housing" of the city of Zelenodolsk.

4. Summary

The simulation results can be summarized in several conclusions.

With an increase in the area of land by 1%, the market value of the land increases by 0.91%. This is understandable, since the increase in the area of land leads to an increase in the value of the land. This feature should not be confused with the specific indicator of market value, which will decrease as the area increases.

With an increase in the distance from the land to Kazan by 1%, the market value of the land will also increase by 3.31%. This controversial feature can be explained. According to the evaluation of zoning, the closer the land to the city of Kazan, the cost is lower. This is due to the fact that in such areas there is an undeveloped infrastructure, which is important for the land of individual housing construction, first of all, it is the social infrastructure, due to the lack of nearby health facilities, education, pre-school education, etc.

If the distance from the land plot to the railway increases by 1%, the market value of the land plot increases by 0.06%. This is due to the fact that the closer the land plot is to the railway, the lower its cost goes, due to the large number of adverse and negative factors, which have already been mentioned in this article.

With an increase in the distance from the land to the nearest recreational area (forest) by 1%, the market value of the land is reduced by 0.05%. For land plots IH this is understandable, since in cities the location of the land near the recreational zone has a positive effect on their cost.

By increasing the distance from the land to the nearest water body by 1%, the market value of the land increases by 0.24%. This is a controversial situation that can be explained. Basically, for land plots with the type of permitted use "For individual residential development" in the city of Zelenodolsk, the Volga river was chosen as the nearest water body. In this settlement along the Volga river there is a number of enterprises, including a shipbuilding plant, a plywood plant, a plant for the production of refrigerators, etc. In this regard, the closer the land plot to the Volga river is, the lower its cost goes.

5. Conclusions

The land market for housing construction in Zelenodolsk demonstrates the classical properties that have already been observed by researchers in similar markets in small towns. On the basis of the study it is possible to rank the factors on the strength of their impact on the change in the cadastral value of the land:

- increasing the distance to the metropolis – Kazan has the maximum impact on the increase in the cadastral value of the land;
- the area of the land plot takes the second place on force of influence on cadastral cost of the land plot, then follows distances from the land plot to the nearest water body;
- the increase in the distance from the land plot to the railway and the distance to the nearest recreational zone (forest area) has a minimal impact on the change in the cadastral value of the land plot.

Our research has shown that the famous saying that the main thing in real estate which is "location, location, location" is also applicable to the land market.

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