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Spatial Autocorrelation in the Analysis of the Land Property Market on the Example of Szczecin and Bydgoszcz

Abstract: The location of the real estate is the most important determinant of its value. Location does not change, therefore the value of real estate strongly depends on factors specific to a given area within a city. Topography influencing a possibility of land development, territorial development, installations and road infrastructure as well as the neighbourhood have great influence over the price of the real estate. All these factors are connected with buyers' preferences and with transactional price, unit price and value of the property. The aim of the paper is to analyse the influence of the relative position of the examined real estates on their prices; and comparison of results obtained for Szczecin and Bydgoszcz. In order to achieve this aim Moran's I Statistic and spatial autoregressive model were applied. The data came from notarial deeds from registers of real estate prices and values concerning transactions on land ownerships on unbuilt land properties in 2014 in Szczecin and Bydgoszcz.

Keywords: land property market, spatial autocorrelation

JEL: C21, R30

1. Introduction

In most cases the purchase of land property is connected with a future decision to build on it. Other than the use of land, there are many elements influencing its value. These elements are also the conditions for the choice of location of a bought land property. The location is very important from the point of view of its market attractiveness (Wang, 2006: 18). Factors determining attractiveness could be as follows: topography influencing a possibility of land development, territorial development, installations and road infrastructure. The details of the local spatial development plan can reduce the possibilities of land use or increase the value of land property. On the other hand the local land development plan also determines the use of neighbouring land properties and neighbourhood significantly influences the value of a given land property (positively or negatively). The neighbourhood effect is very strong on the real estate market (Fujita et al., 1999: 1–6). An attractive neighbourhood creates new locations and an enclave of valuable real estates. Land properties which are highly priced on the local market "transfer" their value onto the neighbouring land properties. Nearby green spaces increase the value of housing estate (Been, Voicu, 2008) unless they are adjacent to a shopping centre (Foryś, 2014: 116–118). Similarly, detrimental features of properties and low-value lands (due to their investment potential) depreciate the value of neighbouring land properties. For example social housing has negative influence on prices in the neighbourhood (Ellen et al., 2007).

In the built-up areas there are local centres of highly priced estates related to prestigious location – so called urban rent. The mechanism of formation of urban rent results from domination of location factor, including savings arising due to accessibility of a given location from other parts of the city (Foryś, Nowak, 2014: 25–26). From this point of view, urban rent in monocentric cities is reciprocally dependent on the distance from the city centre. Nowadays, many cities have sectoral urban structure with more than one centre (local centres). In that case the dependency of price and distance from the centre is not strictly decreasing but is characterised by rises and falls (Figure 1).

The issues connected to so called open spaces also arise, i.e. gaps in building line or in property use. They cause falls and then rises of real estate prices. Due to the reasons mentioned above, it is reasonable to analyse the spatial structures of real estates with similar functions and mutual influence on the prices of various functions of these real estates. It is also essential to ask if markets which are considered similar are characterised by the same spatial relationships.

The aim of the research is to analyse the influence of prices of neighbouring real estates (land properties) on price of a given parcel in Szczecin and Bydgoszcz and a comparison of the obtained results. The hypothesis says that there exists a spatial autocorrelation in Szczecin and Bydgoszcz as far as unit prices are concerned.

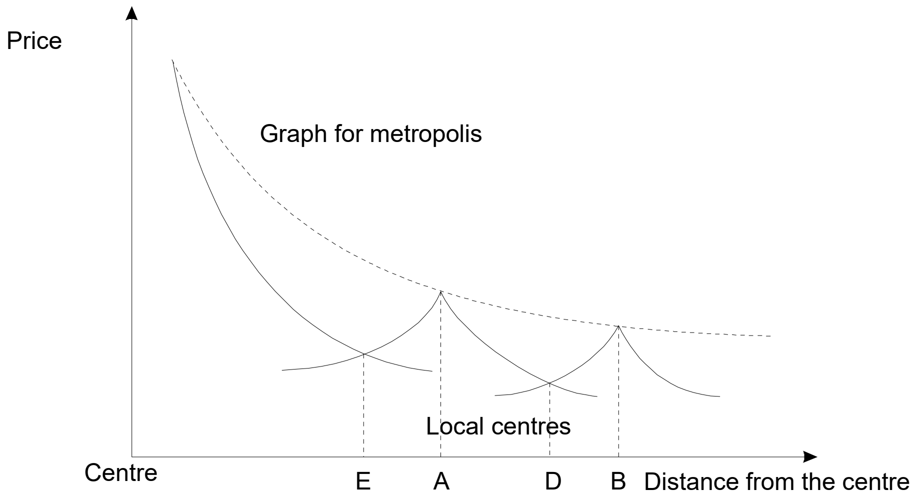

Figure 1. Price and distance from the centre of the city with several local centres

Source: Wurtzebach, Miles 1987: 73

2. Methods applied

At the beginning of the research the distributions of analysed variables were constructed and descriptive statistics were calculated. The uniform and the log-normal distributions were tested. In order to do this Kolmogorov test (Domański, 1990: 51–53) was applied. Additionally relative entropy (Batóg, Foryś, 2014; 2016) as spatial concentration measure was computed.

The entropy measure (E) is given by formula (1).

$$E = -\sum_{k=1}^{n} u_k \log_2 u_k , \qquad (1)$$

where:
n – number of intervals,
k – number of interval,
u_k – share of number of units in interval k in total number of units.

The minimum value of entropy measure is 0, but the maximum value depends on the number of intervals. Therefore the values of the entropy measure were transformed into interval $\langle 0, 1\rangle$ (relative entropy measure). The values of relative entropy close to 0 indicate that analyzed variable is not characterized by uniform distribution but is strongly concentrated.

Then the Moran's I statistic (Anselin, 1998: 17; Arbia, Baltagi, 2009: 110–111), given by formula (2) was calculated.

$$I = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}^{*} z_i^s z_j^s, \tag{2}$$

where:
n – number of objects,

$w_{ij}^{*} = \frac{w_{ij}}{\sum_{j=1}^{n} w_{ij}}$ – elements of standardized weights matrix,

w_{ij} – elements of weights matrix,

z_i^s, z_j^s – standardized values of analysed variable.

The weights matrix was constructed as a connectivity matrix. The entries equalled 1 when objects i and *j* shared common boundary and 0 otherwise.

The statistical significance of Moran's I statistic could be tested by means of statistic *U* given by formula (3) (Suchecki, 2010: 113–114; Lee, Wong, 2001: 82). The null hypothesis says that there is no spatial autocorrelation for analysed variable in a given area.

$$U = \frac{I - E(I)}{\sqrt{\mathrm{var}(I)}} \sim N(0,1), \tag{3}$$

where:

$E(I) = -\frac{1}{n-1}$,

$\mathrm{var}(I) = \frac{n^2 S_1 - n S_2 + 3 S_0^2}{\left(n^2 - 1\right) S_0^2} - \frac{1}{\left(n-1\right)^2}$

$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}$,

$S_1 = \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \left(w_{ij} + w_{ji}\right)^2$,

$S_2 = \sum_{i=1}^{n} \left(w_{i\cdot} + w_{\cdot i}\right)^2$.

At the end of the research an attempt to estimate the spatial autoregression model was made (Suchecki, 2010: 248). The version presented by formula (4) was applied.

$$y = Wy + X\beta + \varepsilon, \tag{4}$$

where:
y – endogenous variable,
W – weights matrix,
X – vector of exogenous variables,
β – parameters,
ε – random error.

3. Data

The data came from notarial deeds from registers of real estate prices and values concerning transactions on unbuilt land properties in 2014 in Szczecin and Bydgoszcz. The land property markets in these cities are comparable. The population of Szczecin is 400 thousand and the population of Bydgoszcz is 350 thousand. The area of Szczecin is about 300 km^2 and the area of Bydgoszcz is about 175 km^2. The area of Szczecin is greater but a significant part of it belongs to Lake Dąbie which accounts for almost 20% of Szczecin area. For the comparison of both markets to be possible, only the parcels assigned for housing development purposes within the local spatial development plans were considered. The research dealt with transactions on right ownerships because the number of transactions on perpetual usufructs was very small. There were 175 transactions in Szczecin and 123 in Bydgoszcz. The analysis was based on the following variables on transactions:
1) date of transaction,
2) transaction price (PLN),
3) parcel area (m^2),
4) location (housing estate).

The study concerned the price of 1 square meter of sold (bought) land, hereafter unit price. It is worth to mention that Szczecin consists of 4 districts and 37 housing estates and Bydgoszcz consists of 7 districts and 43 housing estates.

4. Empirical results

Table 1 shows that mean of unit price is higher in Bydgoszcz than in Szczecin. The reason for that is that in Bydgoszcz there were a few transactions with high unit prices – in such case mean is much higher than median (positive skewness). Looking at positional parameters, one can observe that medians of unit price are almost equal for Szczecin and Bydgoszcz and 50% of transactions is characterised by unit prices in the very similar interval from lower quartile (103.7 PLN in Szczecin, 113.6 PLN in Bydgoszcz) to upper quartile (276.2 PLN in Szczecin, 298.3 PLN in Bydgoszcz).

Table 1 presents basic descriptive parameters for three variables: total price, area of land and unit price. This part of analysis concerns individual transactions.

Table 1. Descriptive parameters

Statistical parameters	Szczecin			Bydgoszcz		
	Total price	Area of land	Unit price	Total price	Area of land	Unit price
Number of transactions	175	175	175	123	123	123
Minimum	60	6	10.00	3000	25	6.35
Maximum	4484400	32756	976.00	4750000	12382	2584.00
Range	4484340	32750	966.00	4747000	12357	2577.65
Mean	306357.91	1775.68	207.32	376545.35	1824.21	256.72
Median	180000	1002	200.91	160000	938	195.46
Standard deviation	547136.81	3326.73	135.14	678785.82	2550.27	285.85
Coefficient of variation	178.59	187.35	65.17	180.27	139.80	111.34
Skewness	5.67	6.41	1.71	3.98	2.79	4.98
Lower quartile	107600	718	103.71	60000	489	113.63
Upper quartile	297000	1340	276.26	350000	2021	298.37

Source: own calculations

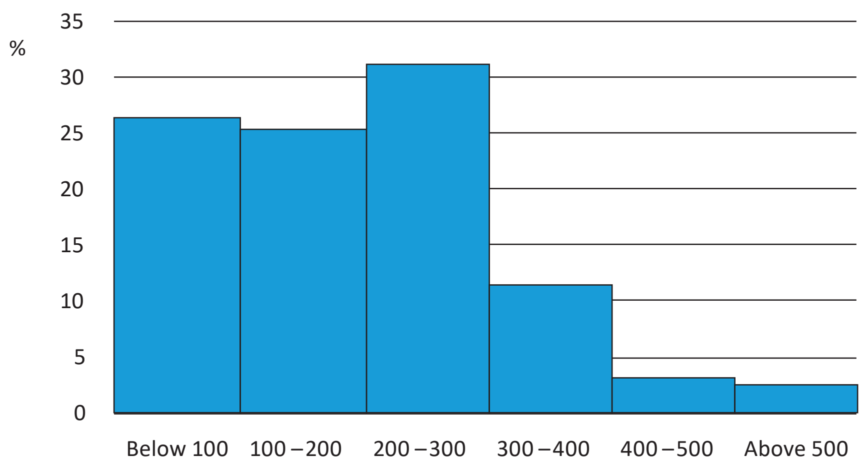

Figure 2. Structure of land properties according to unit prices in Szczecin

Source: own calculations

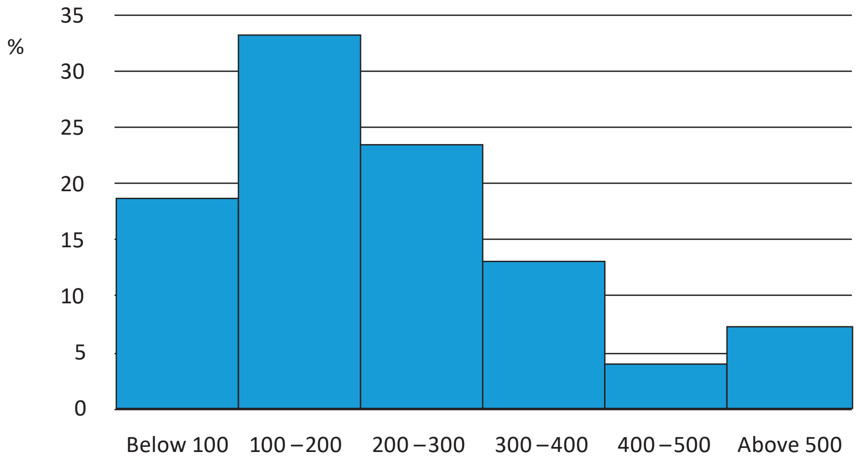

Figure 3. Structure of land properties according to unit prices in Bydgoszcz

Source: own calculations

Figure 2 and Figure 3 present structures of land properties according to unit prices in Szczecin and Bydgoszcz.

Almost all unit prices are below 400 PLN both in Szczecin and in Bydgoszcz. The main difference for these two cities is that the biggest share of transactions in Szczecin has unit price in interval from 200 to 300 PLN whereas in Bydgoszcz the biggest share of transactions has unit price in interval from 100 to 300 PLN.

Table 2 presents the values of relative entropy and the results of Kolmogorov test.

Table 2. Relative entropy and the results of Kolmogorov test for unit price

	Szczecin	**Bydgoszcz**
Relative entropy	0.844	0.897
Statistic in Kolmogorov test for uniform distribution	4.57 ($p < 0.001$)	2.84 ($p < 0.001$)
Statistic in Kolmogorov test for log-normal distribution	1.71 ($p = 0.004$)	1.57 ($p = 0.014$)

Source: own calculations

The high values of relative entropy (close to 1) mean that the distributions of unit prices in Szczecin and Bydgoszcz are not strongly concentrated – there is no unique interval with very high share of transactions. On the other hand the Kolmogorov test allows for rejecting the null hypothesis, saying that the distribution is uniform. Critical value from Kolmogorov distribution equals 1.36 for $\alpha = 0.05$ and both statistics in Kolmogorov test are much higher (4.57 for Szczecin and 2.84 for Bydgoszcz). The Kolmogorov test also allows for rejecting the null hypothesis, saying that the distribution is log-normal although the test statistics are only a little higher than the critical value in both cities.

In the next part of the study the average unit prices were calculated for every housing estate. Figure 4 and Figure 5 present the spatial autocorrelation in Szczecin and Bydgoszcz. For a given point the value on horizontal axis represents standardized average unit price for housing estate and the value on vertical axis represents the average of standardized average unit prices of neighbouring housing estates. In both Figures the most points are located in the first and in the third quarter of the coordinate system. It means that there is a positive spatial autocorrelation in Szczecin and in Bydgoszcz.

The value of Moran's I statistic for Szczecin equals 0.544. This value is quite high and means that housing estates with high values of average unit price neighbour with housing estates with similarly high values of average unit price. The statistical significance of spatial autocorrelation was tested. The value of u statistic equalled 2.653. The critical value for significance level 0.05 equals 1.96. Therefore null hypothesis, saying that there is no spatial autocorrelation could be rejected.

In case of Bydgoszcz the value of Moran's I statistic equals 0.379. The value of u statistic equalled 3.015. Therefore, although I statistic is lower for Bydgoszcz than for Szczecin the null hypothesis, saying that there is no spatial autocorrelation in Bydgoszcz could also be rejected.

At the end of the study the spatial autoregression models were estimated. The results of estimation are presented in Table 3 and Table 4.

Figure 4. Scatterplot for average unit prices for housing estates in Szczecin

Source: own calculations

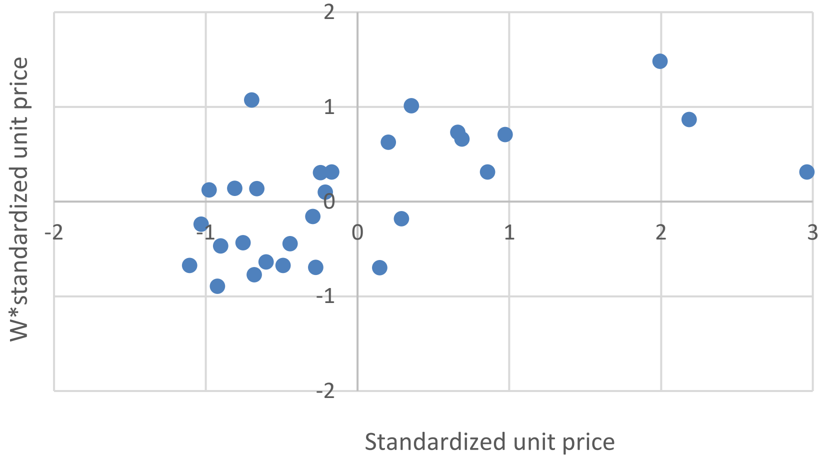

Figure 5. Scatterplot for average unit prices for housing estates in Bydgoszcz

Source: own calculations

Table 3. Estimated spatial autoregression model for average unit prices in Szczecin

	Parameter	Standard error	t Statistics	p-value
Constant	154.2520	64.3218	2.3981	0.0282
$W \cdot$ Unit price	0.7271	0.1900	3.8260	0.0014
Area	–0.0042	0.0016	–2.6070	0.0184
$R^2 = 0.6018$ $S_e = 123.4180$ $F = 12.462$, $p = 0.0000$				

Source: own calculations

Table 4. Estimated spatial autoregression model for average unit prices in Bydgoszcz

	Parameter	Standard error	t Statistics	p-value
Constant	3.3238	117.9953	0.0281	0.9777
$W \cdot$ Unit price	0.9378	0.2818	3.3280	0.0026
Area	–0.0001	0.0046	–0.0209	0.9835
$R^2 = 0.3573$ $S_e = 215.2855$ $F = 7.2275$, $p = 0.0032$				

Source: own calculations

The results of estimation of spatial autoregression model for Szczecin are good. Parameters are statistically significant and coefficient of determination is above 0.6. The sign of parameter for variable area is negative, which means that the unit prices are smaller in Szczecin for greater land properties.

The results of estimation of spatial autoregression model for Bydgoszcz are different. Coefficient of determination is quite small and the parameter for variable area is not statistically significant. It means that in Bydgoszcz there is no relationship between area and unit price.

5. Conclusions

The following findings for unit prices could be stated on the basis of the conducted study:

1) positional intervals of variation were very similar in both cities,
2) the biggest share of transactions was in interval 200–300 PLN in Szczecin, and in interval 100–200 PLN in Bydgoszcz,
3) entropy was very high for both cities, but distributions were not uniform,
4) Moran's I statistic was significant ($\alpha = 0.05$) in both cities,
5) Moran's I statistic was on moderate level (higher in Szczecin than in Bydgoszcz), which means that autocorrelation exists and is not strong,
6) there was a spatial dependence of unit price and area in Szczecin, and not in Bydgoszcz.

The results obtained on the basis of the research could be very useful for participants of land property market, especially for real estate appraisers. The real estate appraisers are interested in relationships between local real estate markets and attributes of real estates on a given market.

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Autokorelacja przestrzenna w analizie rynku nieruchomości gruntowych na przykładzie Szczecina i Bydgoszczy

Streszczenie: Lokalizacja nieruchomości w przestrzeni jest jedną z najistotniejszych determinant jej wartości. Stałość w miejscu powoduje, iż nieruchomości każdego rodzaju pozostają pod wpływem czynników właściwych dla danego położenia w przestrzeni. Zarówno ustalenia planistyczne, dostęp do drogi publicznej, jak również ukształtowanie terenu czy warunki gruntowo-wodne są cechami wpływającymi na wartość nieruchomości – podobnie jak sąsiedztwo innych nieruchomości o lepszych lub gorszych atrybutach. Wzajemne oddziaływanie nieruchomości jest szczególnie widoczne w preferencjach nabywców na rynku, a w efekcie przekłada się na ich cenę transakcyjną, cenę jednostkową oraz na ich wartość. Celem artykułu jest zbadanie wpływu wzajemnego położenia analizowanych nieruchomości na ich ceny i porównanie otrzymanych wyników dla Szczecina i Bydgoszczy. W analizie zastosowano statystykę I Morana oraz przestrzenne modele autoregresyjne. Wykorzystano dane dotyczące transakcji na rynku nieruchomości gruntowych niezabudowanych w 2014 roku w Szczecinie i Bydgoszczy.

Słowa kluczowe: rynek nieruchomości gruntowych, autokorelacja przestrzenna

JEL: C21, R30

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