

Spatiotemporal Analysis of the Activity of Residential Development in Poland

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Abstract. The objective of the study presented in the article is to determine the spatial diversification and determinants of construction activity in Poland between 2006 and 2015. Theoretical hypotheses and observations of behaviour of economic entities clearly show that their decisions depend both on the situation in local and regional markets, as well as distances from other regions or local markets. The number and the surface area of completed residential units, as well as the number of completed buildings and issued construction permits, were adopted as the measures of construction activity. The analysis also includes selected demographic, social and economic indices characterising the individual territorial units in Poland on the basis of the local data bank maintained by the Central Statistical Office. In the course of the study, spatial panel models were used, and as a result of the study, construction activity models were obtained, taking spatial interactions into account.

Keywords: housing activity, panel data analysis, spatial modelling.

Conference topic: Sustainable urban development.

Introduction

Housing needs have a common dimension and refer to all residents throughout the entire period of human life, whereas fulfilment of such needs constitutes a basic and fundamental challenge for consumption (Belej, Cellmer 2014; Borowski 2015; Lepkova *et al.* 2016). According to Trojanek (2008), housing needs are the determinant of the social function as the basic element of satisfying human needs, and the economic function, as the basic object of investments. A house constitutes the most expensive of all goods purchased throughout people's lives, and many citizens cannot afford their own place to live within their lifetime. The housing situation of citizens influences professional activity, qualifications and the spatial mobility of employees. Among numerous economic and sociological theories, there is unanimity with respect to the extraordinary significance of the housing market in the life of the individual, society and state (Nykiel 2012).

According to Urbanavičienė *et al.* (2009), the growth or decline of the housing sector considerably affects the general growth or decline of a country's economy. The real estate market share in the global economy suggests the important position of this market in the economic processes of major economies (Venclauskienė, Snieška 2011). A housing policy is pursued by the state and by the local government by fostering conditions conducive for satisfying the residential needs of the society. In the conditions of market economy, functioning of the housing market, its efficiency in allocating the existing resources and the possibilities of creating new supply adequate in terms of quality and quantity to the notified demand constitute the outcome of quite a numerous group of economic and non-economic factors.

Previous studies

Studies of housing markets and their mutual relations with the social or economic environment have been pursued in literature on the subject both in qualitative and in quantitative approaches. In Tibaijuk's studies (2013), it was shown that improvement in housing conditions means a drop in expenses on health care; it also facilitates economic development and ensures mobility of the labour force and, primarily, mobilises households to accumulate funds and save for residential purposes. Strzeszyński (2009) performed a comparative analysis of the indices of the Polish housing market using the costs of construction of residential buildings, number of construction permits, number of initiated construction processes in the housing market, number of commissioned flats and average surface of commissioned flats. According to Glasser *et al.* (2005), limited regulations and lower population density facilitate the process of development of the housing market and increase employment. In contrast to this, excessive regulations, in particular blocking of urban space, increases the prices of land, leading to high costs for the construction of flats.

The impact of macroeconomic factors on the functioning of housing markets in selected countries was evaluated by Adams and Fuss (2010) on the basis of panel data encompassing 15 countries over 30 years. The results of studies

on the diversity of construction activity in a spatial approach were presented by Beenstock and Felsenstein (2015), using non-stationary panel data pertaining to selected areas in Israel. The main determinants of diversity were, in this case, prices of real estate and construction costs. Foryś and Batóg (2016), using the spatial-temporal analogy method, conducted studies on the similarity of intensity and variability in time of the number of transactions pertaining to residential premises, the ratio between the number of completed residential units and the number of transactions pertaining to residential premises and the number of residential units for which construction permits were procured in every province in Poland. As a result of such studies, it was determined that an increase or weakening of activity in the housing market, as well as the values of variables describing such market, are shifted in time (delayed) in less developed markets in comparison to better developed markets. Spatial diversity of the construction activity is also described by Broitman and Koomen (2015), who show various hierarchical levels of spatial division, pointing out the various levels of dynamics of economic phenomena between rural and urban areas and suburban areas.

The activity in the housing market is greatly influenced by the interaction between variables describing the macroeconomic environment and factors characterising demand, supply and prices (Beltratti, Morana 2010); simultaneously, according to Orenstein and Hamburg (2010), this phenomenon manifests great variability in time and space. Reed (2016) conducted studies related to the dynamics of permits granted for residential construction and commenced construction processes in the housing market in the USA, Australia, Canada and France. In the study, the author adopted an assumption that the index of the number of construction permits along with commenced investments are the key measures for the level of economic activity, whose behaviour takes into account the effects of the global financial crisis. As a result of such studies, it was shown that the global character of connected housing markets and high level of demographic migration constitute the main factors of activity of housing markets. Meen (2012) conducted spatial analysis on housing markets among others by explaining the spatial interactions between regional housing markets and the ripple effect, qualitative response models to examine household formation, moving decisions and location choice, joint models of prices and construction in the stock-flow tradition, empirical estimates of the most important elasticities from house price equations, which included both long-run elasticities and nature of lags.

Data and methods

The study was performed in Poland. The data used for analyses refers to the period from 2005 to 2014 and derives from the local data bank maintained by the Central Statistical Office of Poland (stat.gov.pl). A poviats was adopted as a statistical unit, in line with the nomenclature of statistical territorial units adopted for statistical purposes in Poland, prepared on the basis of the European Nomenclature of Territorial Units for Statistics (NUTS). Among the many factors testifying to construction activity, those selected mainly testify to the number of completed residential units and the number of construction permits pertaining to new residential buildings. These values were presented in a relative approach, which allowed for avoiding correlation with the surface and the number of people residing in the area of a given statistical unit. Furthermore, data concerning basic social and economic indices was collected for each studied unit. The breakdown of adopted indices and their markings are presented in Table 1. In general, data for 380 poviats was collected.

Basic analyses were performed with the use of spatial modelling of panel data, i.e. data that results from joining the time series of several observations for individual units. In classic panel models, it is assumed that the shape of the response variable is influenced, apart from explanatory variables, by non-measurable factors that are fixed in time and specific for a given period, known as time effects. The general form of the panel model may be presented as follows (Baltagi 2008):

$$y_{it} = \beta_0 + \sum_{k=1}^k \beta_{kit} x_{kit} + \alpha_i + v_t + \varepsilon_{it}, \quad (1)$$

where y_{it} denotes the response variable, x_{kit} denotes the explanatory variable, β_0 is the absolute term, and β_{kit} is the structural parameter of the model (i denotes item, t denotes time, and k denotes the number of the explanatory variable). Additionally, α_i denotes individual effects, v_t denotes periodical effects, and ε_{it} denotes the random disrupting factor. Individual and periodical effects may be agreed upon effects, i.e. fixed in time or fixed for a given unit, and in such case, they do not depend on random factors (FE – Fixed Effects Model). In the case of models with random effects (RE – Random Effect Model), each unit is assigned a certain random variable, whose implementation is responsible for the individual effect in a given period. Consequently, the individual effects are not treated as parameters.

One of the problems concerning construction and estimation of models for panel data is taking into consideration spatial interactions in a cross-section dimension for data that can be located in a geographic space (Yang *et al.* 2006). Theoretical hypotheses and observations of behaviour of economic entities clearly show that their decisions depend both on the situation in local and regional markets, as well as distance from other regions or local markets (Porter 2000; Forsberg, Lindgren 2015). This phenomenon also refers to the housing market (Ioannides, Zabel 2003; Jones, Leishman 2006). Thence, in panel modelling, it is recommended to take into account the effects resulting from globalisation. In this case, defining the manner of including the interaction mechanism in time and space may be a problem. One of the simplest possibilities is to adopt an assumption that the function of distance between spatial units is identical in all periods.

Table 1. Indices adopted for analyses (Source: own study)

Indicator	Housing activity / Social and economic conditions
Y ₁	Completed dwelling units per 1,000 population
Y ₂	Total usable floor area of completed dwelling units per person
Y ₃	Completed new residential buildings per 1,000 population
Y ₄	Construction permits for new residential buildings per 1,000 population
X ₁	Births per 1,000 population
X ₂	Share of mobile working age population in total population
X ₃	Population density (person/km ²)
X ₄	Marriages contracted by 1,000 population
X ₅	Registered unemployment rate
X ₆	Migration rate per 1,000 population
X ₇	Entities entered into register of business entities (REGON) per 1,000 population
X ₈	Commune budget income per inhabitant
X ₉	Average usable floor area of a dwelling unit per person
X ₁₀	Average gross monthly remuneration

The panel model with spatial autoregression of the response variable for variables in the form of two-dimensional columns, the elements of which are observations changing in space ($i = 1, 2, \dots, N$) and in time ($t = 1, 2, \dots, T$), may be expressed as follows (Anselin *et al.* 2008; Baltagi 2008):

$$y = \rho(I_T \otimes W_N)y + X\beta + \varepsilon. \quad (2)$$

After transformation to a reduced form, where variable Y is the function of exogenous variables and the random factor from various locations, we receive (Anselin *et al.* 2008; Baltagi 2008):

$$\left[I_T \otimes (I_N - \rho W_N) \right]^{-1} y = X\beta + \varepsilon; \quad (3)$$

$$y = \rho \left[I_T \otimes (I_N - \rho W_N) \right]^{-1} X\beta + \left[I_T \otimes (I_N - \rho W_N) \right]^{-1} \varepsilon. \quad (4)$$

Inclusion of group effects, μ (FE or RE) in the panel model, offers the following form:

$$y = \rho(I_T \otimes W_N)y + X\beta + (i_T \otimes I_N)\mu + (I_T \otimes I_N)\varepsilon, \quad (5)$$

where i_T is a T -element vector of ones.

When autocorrelation of the random factors is taken into account in the panel model, there is a choice between direct definition of the functional form of interaction and application of a relevant process of the random factor (e.g. 1st order autoregression). In the case of applying the random factor in the model of the spatial autoregression process, the variance-covariance matrix has the following form (Anselin *et al.* 2008):

$$\Omega_{NT} = \sigma^2 \left\{ I_T \otimes \left[(I_N - \lambda W_N)^T (I_N - \lambda W_N) \right]^{-1} \right\}. \quad (6)$$

If specific effects are taken into account, in the case of application of the random factor in the model of the 1st order spatial autoregression process, the panel model may be defined as follows (Baltagi 2008):

$$y = X\beta + (i_T \otimes I_N)\mu + \left[I_T \otimes (I_N - \lambda W_N) \right]^{-1} \varepsilon. \quad (7)$$

In the course of the study, panel models with spatial autoregression were used, both the response variable and the random factor including the fixed effects (FE) and random effects (RE). The model with spatial autoregression of the response variable, taking fixed effects into account (SAR-FE – Spatial Autoregressive Fixed Effect Model), may be presented in the following simplified form:

$$y_{it} = \alpha_i + x_{it}^T \beta + \rho(Wy)_{it} + u_{it}, \quad u_{it} \sim N(0, \sigma_u^2). \quad (8)$$

On the other hand, taking into account the random effects (SAR-FE – Spatial Autoregressive Random Effect Model), the form of the model will be as follows:

$$y_{it} = \alpha_0 + x_{it}^T \beta + \rho (Wy)_{it} + v_{it};$$

$$v_{it} = \alpha_i + u_{it},$$
(9)

where ρ denotes the spatial lag parameter (autoregression), whereas $(Wy)_{it}$ denotes relevant observation of spatial image of the response variable in the i^{th} location in t period.

The model with fixed effects taking spatial correlation of the random factor (SE-FE – Spatial Error Fixed Effect Model) has the following form:

$$y_{it} = \alpha_i + x_{it}^T \beta + u_{it};$$

$$u_{it} = \lambda (Wu)_{it} + \varepsilon_{it}, \quad \varepsilon_{it} \sim N(0, \sigma_\varepsilon^2).$$
(10)

On the other hand, the model with random effects (SE-RE – Spatial Error Random Effects Model) may be presented as follows:

$$y_{it} = \alpha_0 + x_{it}^T \beta + v_{it};$$

$$v_{it} = \alpha_i + u_{it};$$

$$u_{it} = \lambda (Wu)_{it} + \varepsilon_{it}, \quad \varepsilon_{it} \sim N(0, \sigma_\varepsilon^2),$$
(11)

where λ denotes the spatial autocorrelation parameter of the random factor.

To verify the existence of spatial interactions, the marginal LM test for spatial error correlation or random effects was applied (Baltagi *et al.* 2003), as a result of which it was also determined whether it is justified to introduce regional effects to the model. To choose the proper form of the model, locally robust LM tests for spatial lag correlation and sub-spatial error correlation (Anselin *et al.* 1996; Elhorst 2014) were applied. With the use of this test, the type of spatial dependency was determined (spatial lag or spatial error). To confirm the results, Hausman's test was also used (Millo, Piras 2012).

Study results and discussion

Construction activity in the housing market in Poland in the last ten years was subject to quite significant fluctuations. The highest values of adopted indices (from Y1 to Y4) were noted in 2008; subsequently, there was a slight drop. In the last year, it was possible to notice a certain recovery, which, in particular, pertained to the number of completed residential units (Fig. 1).

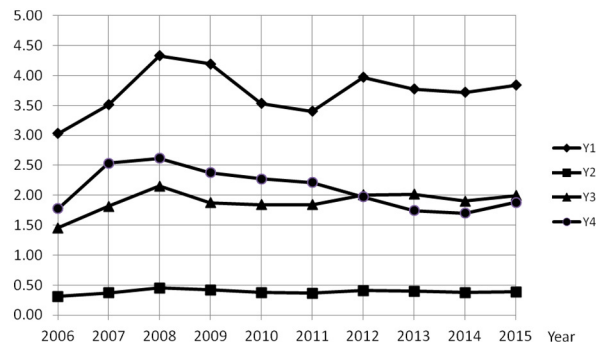


Fig. 1. Dynamics of selected indices of housing construction activity. Y₁ – completed dwelling units per 1,000 population, Y₂ – total usable floor area of completed dwelling units per person, Y₃ – completed new residential buildings per 1,000 population, Y₄ – construction permits for new residential buildings per 1,000 population (Source: own study)

In the course of the study, it was assumed that spatial correlations among the examined units, expressed in the form of weight matrix, will be built according to the common border criterion (first order matrix, queen contiguity). Global Moran's I calculated for individual explanatory variables indicates that Y₁ and Y₂ variables are characterised by a relatively high spatial autocorrelation. They assume the value of 0.404 and 0.301, respectively, whereas the hypothesis concerning the lack of spatial autocorrelation was rejected at a level of significance lower than 0.001. In the case of the Y₃ variable, the level of significance amounted to 0.024, whereas the value of Moran's I for the Y₄ variable indicates the absence of spatial autocorrelation (the level of significance amounted to 0.163). As an example, Fig. 2 presents the spatial distribution of the Y₁ variable (completed residential units per 1,000 population), which is characterised by a clear spatial structure.

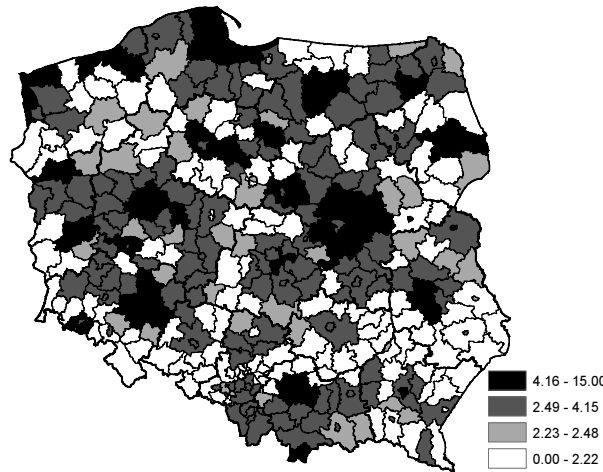


Fig. 2. Average number of residential units completed between 2006 and 2015 in conversion per 1,000 population (Source: own study)

Based on the spatial distribution of the activity of housing construction, it may be ascertained that such activity focuses primarily in the vicinity of larger cities. This may be the manifestation of the phenomenon of suburbanisation, resulting from a limited supply of land assigned for new housing investments in rural areas. Relatively high construction activity in the vicinity of larger cities may also be related to the relatively high prices of flats built in larger cities, which incline people to migrate to rural areas.

In the course of the study, an assumption was made about the linear form of models describing dependencies between the selected construction activity indices and social and economic factors. The results of tests, on the basis of which selection of the proper form of the model was made, are presented in Table 2.

Table 2. Results of tests enabling selection of a proper form of the model. P level of significance is specified in brackets (Source: own study)

Type of test	Dependent variable in model			
	Y ₁	Y ₂	Y ₃	Y ₄
marginal LM test (SLM1)	0.013 (0.989)	0.011 (0.991)	0.016 (0.987)	0.015 (0.988)
marginal LM test (SLM2)	0.002 (0.998)	0.002 (0.998)	0.001 (0.999)	0.002 (0.998)
LM test for spatial error dependence	73.309 (<0.001)	48.848 (<0.001)	23.328 (<0.001)	51.855 (<0.001)
LM test for spatial lag dependence	9.967 (0.002)	11.686 (0.001)	12.020 (0.001)	28.354 (<0.001)
Hausman test (χ^2)	532.65 (<0.001)	290.05 (<0.001)	5292.00 (<0.001)	1438.20 (<0.001)

The results of the marginal LM test clearly indicate that there are no bases for rejecting the hypothesis concerning the significance of random effects in individual models. This was also confirmed by Hausman's test. This means that there are differences fixed in time between units, e.g. each examined unit has its own specific part of variability, whereas it is not recommended to separate effects specific for individual periods. The test specifying the type of dependency (spatial error or spatial lag) in all models indicates the significance of both the spatial error models and the spatial lag models. However, the choice of the model was determined by the lower significance level of the spatial error model. The performed tests show that proper models describing the dependency between indices characterising construction activity and variables describing social and economic determinants are the spatial error models with fixed effects. This means that there are differences between units that are fixed in time.

In the course of the study, four models were built, where the response variables were the values of Y₁, Y₂, Y₃ and Y₄, whereas the explanatory variables were the factors described in Table 1 as X₁, X₂, ..., X₁₀. Table 3 presents the parameters of individual models.

Table 3. Parameters of panel models of the spatial error for individual response variables from Y_1 to Y_4 . In brackets, p level of significance is specified, ρ denotes spatial autocorrelation index, whereas $\beta_1, \beta_2, \dots, \beta_{10}$ constitute model parameters (Source: own study)

Parameter	Dependent variable			
	Y_1	Y_2	Y_3	Y_4
ρ	0.147 (<0.001)	0.175 (<0.001)	0.161 (<0.001)	0.212 (<0.001)
β_1	0.098 (<0.001)	0.008 (<0.001)	-0.029 (0.042)	-0.018 (0.163)
β_2	0.154 (<0.001)	0.021 (<0.001)	0.122 (<0.001)	0.089 (<0.001)
β_3	-0.001 (0.004)	-1.4e-04 (0.002)	-5.4e-04 (0.088)	-0.002 (<0.001)
β_4	0.074 (0.040)	0.004 (0.146)	0.060 (0.007)	0.245 (<0.001)
β_5	-0.045 (<0.001)	0.005 (<0.001)	-0.041 (<0.001)	-0.035 (<0.001)
β_6	0.123 (<0.001)	0.011 (<0.001)	0.064 (<0.001)	0.123 (<0.001)
β_7	0.012 (0.394)	-9.0e-04 (0.466)	-0.014 (0.117)	-0.002 (0.842)
β_8	-1.4e-04 (0.058)	-1.6e-05 (0.009)	-1.7e-04 (<0.001)	3.6e-04 (<0.001)
β_9	0.011 (0.729)	0.002 (0.483)	0.131 (<0.001)	-0.348 (<0.001)
β_{10}	6.4e-04 (<0.001)	6.6e-05 (<0.001)	2.0e-04 (0.003)	4.2e-04 (<0.001)

In the model where the response variable is the number of completed residential units per 1,000 population (Y_1), the insignificant variables (on the level of significance below 0.05) turned out to be the number of entities entered in the REGON register per 10,000 population (X_7), as well as municipality budget income in conversion per inhabitant (X_8). The remaining variables are statistically significant. The following variables had the greatest significance (lowest level of parameter significance) in this case: X_2 (percentage of people of mobile working age in the total population) and X_6 (migration balance per 1,000 population). In the second model, where the response variable was the total surface area of residential units completed per person (Y_2), variable X_4 (marriages concluded per 1,000 people) also turned out to be insignificant, whereas the remaining variables showed a significant impact on the response variable. In the case of the Y_3 response variable (number of new residential buildings completed per 1,000 population), the absence of a significant relation refers to variable X_3 (population density) and variable X_7 . In the fourth model, variable X_1 (population growth per 1,000 population) and X_7 turned out to be statistically insignificant. In all models, population density (X_3) was an inhibitor. This confirms the hypothesis that construction activity in densely populated areas may be limited by the relatively small supply of land (in relative terms) assigned for residential investments.

The adopted form of models (models with fixed effects) means that an individual effect is assigned to every spatial unit, which indicates differences in construction activity resulting from factors other than the ones that were included as explanatory variables. These effects may result from specific determinants related to location. As an example, Fig. 3 presents areas of clusters where poviats with high and low values of individual effects are significantly correlated in space. This refers to the model where the response variable is the number of construction permits for new residential buildings per 1,000 population. Clusters were designated pursuant to the local statistics of Getis and Ord (1995).

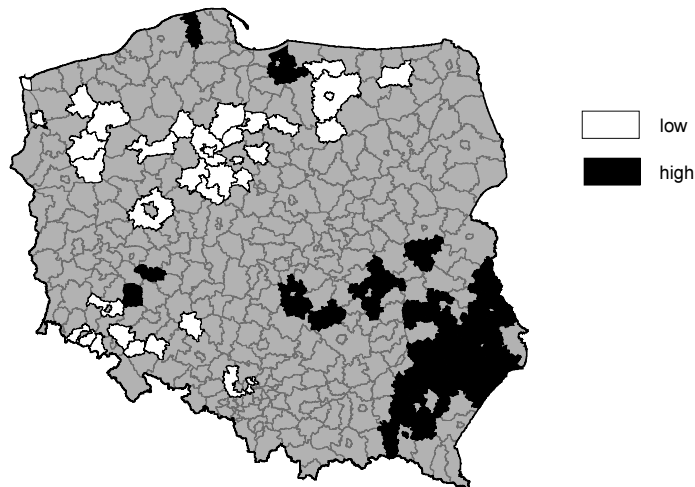


Fig. 3. Clusters of areas with high and low values of individual effects in the spatial panel model for explanatory variable Y_4 (number of construction permits for new residential buildings per 1,000 population) (Source: own study)

In the group of poviats in the south-eastern part of Poland, individual effects show that the location factor may play an important role. Diversification of the values of individual effects may present certain tendencies in space and, in particular, the impact of factors other than the ones which were included in the study on construction activity.

Conclusions

The performed study has shown that both economic and social factors have significant impact on the activity indices of residential development. Among the significant explanatory variables in each model, it is necessary to list the percentage of people of mobile working age in the population in total, the percentage of registered unemployment, the migration balance per 1,000 people and the average monthly gross remuneration. Even though the regularities of distribution of selected indices in space are to be determined as moderate, the application of spatial panel models seems justified in this case. In the course of studies on units which are located in space, overlooking the aspects of spatial ties may lead to a burden on the estimation results and, in consequence, the conclusions.

During the study, it was ascertained that individual units (poviats) are characterised by individual features which have to be taken into account in the course of modelling. The occurrence of individual effects confirms the validity of examining construction activity in a spatial context, where its level is influenced by specific characteristics related to geographic location.

It may be concluded on the basis of the accumulated data that after a period of tumultuous changes in the real estate market, there has been relative stability in recent years, and – in the last year – also slight growth, which may be a symptom of recovery in the residential construction sector. Nevertheless, statistical tests encompassing identification of individual temporal effects do not show the important impact of time, which simultaneously denotes a relatively high differentiation of the dynamics of changes in the construction activity in individual units.

Undoubtedly, development of residential construction depends upon the economic situation, which is primarily influenced by macroeconomic determinants. However, the studies confirm that local factors are also significant in this context. It is likewise necessary to take into account the fact that there are numerous mutual interactions among the examined indices, which means that a recovery of construction activity may also constitute a development factor, both local and regional.

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