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SPATIAL DURBIN PANEL MODEL IN ANALYSIS OF MIGRATION PROCESSES IN EUROPEAN CITIES

Abstract: The aim of the article is to present results of spatio-temporal analysis of foreign net migration level per 1000 people in 271 European cities in the time span 2005–2012 using the spatial autoregressive panel Durbin model. The spatial lags of the dependent and independent variables are taken into account. By including lag effects, we introduce the spatial interactions in migration processes. We state that the net migration in cities is spatially dependent, differentiate and determined by defined phenomena and the presented research method is an adequate technique in such analyses.

Key words: cites, migration processes, net migration, ESDA, spatial weights matrixes, spatial Durbin panel model, spatial lag panel data model

JEL codes: C21, C22, F2, O15

1. Introduction

The free movement of people in the majority of Europe has resulted from many historical changes. The Schengen Area, European Union and gradual introduction of the common currency have made migration not only possible but also common. That is why Europe has become a continent of migration in the 21st century. Intra-European Union mobility has substantially increased over the last decade. Therefore, issues connected with causes, effects and directions of people's movements are becoming an increasingly frequent topic of political and academic discussions.

The specialist literature typically considers issues of migration in the context of a country or region. Empirical studies rarely concern cities. According to estimates, over 25% of the population are first-generation immigrants in major European cities, such as London, Frankfurt, Amsterdam and Brussels (European Urban Knowledge Network, 2012, p. 8). Migrations greatly influence the features of contemporary cities – their size, number of residents, social, cultural, political and economic reality. Thus, analyses of migration processes in European cities are becoming an issue important to researchers.

The migration-related literature provides an infinite number of factors that are likely to affect a decision to move, including social, demographic, cultural, psychological, environmental, political and economic aspects, which may occur at the same time (Bonifazi *et al.*, 2008, p. 20). Nevertheless, the most important aspects are connected with seeking better living conditions and better jobs. For young people, a common motive is also willingness to acquire education at prestigious universities and live in a vibrant city which is a centre of culture and entertainment.

The aim of the article is to present results of the spatio-temporal analysis of foreign net migration per 1000 of the population in selected European cities using the spatial autoregressive Durbin panel model. That model is applied to estimate the impact of socio-economic variables (*e.g.* unemployment, crude birth rate, women per 100 men) on the net migration level as well as to verify the hypothesis on the occurrence of spatial interactions within the scope of that phenomenon. The study is carried out on statistical data concerning 271 European cities in the 2005–2012 period published by the Eurostat.

The study consists of five parts. The first part is an introduction to the issues of foreign migrations in European cities. The second one presents methods applied in the analysis of migration – the spatial autoregressive Durbin panel model and spatial weights matrix built for the purpose of the study. The third part is a short overview of research into migration processes based on the specialist literature. The fourth one describes the statistical databank used in the study and discusses in detail and compares results of the analyses of foreign net migrations in European cities. The fifth part sums up the article and sets directions for further research.

2. Theoretical Background – Spatial Durbin Panel Model

2.1. Spatial Durbin Model

The Spatial Durbin Model (SDM) is a tool which, in its structure, simultaneously assumes taking into account spatial autoregression (*i.e.* an impact of spatially lagged values of the studied endogenous variable on its levels in different locations) and cross regression (*i.e.* an impact of spatially non-lagged and lagged exogenous variables) (Anselin, 1988, LeSage, Pace, 2009):

$$\mathrm{y} = \rho\mathbf{Wy} + \mathbf{X\beta} + \mathbf{WX\gamma} + \boldsymbol{\varepsilon}\,;\ \boldsymbol{\varepsilon}\colon N(\mathbf{0}, \sigma^2\mathbf{I}) \qquad (1),$$

where: $\mathbf{y}$ – vector of endogenous variable values, $\mathbf{X}$ – vector/matrix of exogenous variables, $\mathbf{W}$ – spatial weights matrix of NxN dimensions and zero diagonal elements standardized in rows, ρ – spatial autoregression parameter, $\boldsymbol{\beta}$ – vector of structural parameters, $\boldsymbol{\gamma}$ – vector of spatial image parameters of selected independent variables.

The estimation of model parameters enables to measure the strength and direction of spatial interactions.

2.2. Spatial Panel Data Models

The use of panel data allows to simultaneously consider both information about temporal changes and individual specificity of observed objects in modelling. Moreover, including spatial interactions (taking place in time and in the cross-sectional dimension) in research makes it possible to observe and identify supraregional associations, which determine the course of the phenomenon in a given region and regions situated at a certain geographical distance (Elhorst, 2003, pp. 244–268).

Similarly to spatial regression models[1], spatial interactions in panel models may be considered in various ways, i.e. as spatial autoregression processes of the dependent variable (Spatial Autoregressive, SAR), autocorrelation of the random element (Spatial Error Model, SEM) and spatial "lags" of independent variables (Spatial Crossregressive Model, SCM). Models taking into account the occurrence of spatial interactions among units (spatial autoregression and autocorrelation) and spatial heterogeneity of objects (spatial structure diversification) include, among others, a model with fixed effects and spatial autoregression of the dependent variable (SAR-FEM, Spatial Autoregressive Fixed Effects Model):

$$y_{it}=\alpha_i+\mathbf{x}_{it}^T\boldsymbol{\beta}+\rho\mathbf{W}y_{it}+u_{it},\, u_{it}\sim N(0,\sigma_u^2) \qquad (2).$$

In turn, a model with fixed effects and spatial autocorrelation of the random element (SE-FEM, Spatial Error Fixed Effects Model) can be denoted as follows:

$$y_{it}=\alpha_i+\mathbf{x}_{it}^T\boldsymbol{\beta}+u_{it},\ u_{it}=\lambda\mathbf{W}u_{it}+\varepsilon_{it},\, \varepsilon_{it}\sim N(0,\, \sigma_\varepsilon^2) \qquad (3),$$

where: λ – spatial autocorrelation (autoregression) parameter of the random element.

On the other hand, SAR-REM (Spatial Autoregressive Random Effects Model) is a model with random effects and spatial autoregression of the dependent variable:

$$y_{it}=\alpha_0+\mathbf{x}_{it}^T\boldsymbol{\beta}+\rho\mathbf{W}y_{it}+v_{it},\, v_{it}=\alpha_i+u_{it} \qquad (4).$$

Another basic spatial panel model is a model with random effects and spatial autocorrelation of the random element (SE-REM, Spatial Error Random Effects Model)[2]:

$$y_{it}=\alpha_0+\mathbf{x}_{it}^T\boldsymbol{\beta}+v_{it},\, v_{it}=\alpha_i+u_{it},\, u_{it}=\lambda\mathbf{W}u_{it}+\varepsilon_{it},\, \varepsilon_{it}\sim N(0,\, \sigma_\varepsilon^2) \qquad (5).$$

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1 more in *e.g.* (Suchecki, 2010).

2 There are also models with *two-way* effects; more in, *e.g.* (Suchecki, 2012, pp. 104).

2.3. Spatial Durbin Panel Model – Fixed and Random Effects

Models that take into consideration both spatial autoregression and cross-regression effects, *i.e.* an impact of spatially non-lagged and lagged exogenous variables, and explain differences in levels of various objects in a given period and differences in levels of a selected object in selected sample periods, are mixed spatial panel models (SDPMs, Spatial Durbin Panel Models) (Anselin, 2008, pp. 625–660; Elhorst, 2003, pp. 244–268). Commonly used models of that type include, among others, the Spatial Durbin Fixed Effects Model (SD-FEM):

$$y_{it} = \alpha_i + \rho \mathbf{W} y_{it} + \mathbf{x}_{it}^T \boldsymbol{\beta} + \mathbf{W}\mathbf{x}_{it}^T \gamma + \varepsilon_{it} \qquad (6).$$

In turn, the Spatial Durbin Random Effects Model (SD-REM) can be represented as:

$$y_{it} = \alpha_0 + \rho \mathbf{W} y_{it} + \mathbf{x}_{it}^T \boldsymbol{\beta} + \mathbf{W}\mathbf{x}_{it}^T \gamma + v_{it},\ v_{it} = \alpha_i + u_{it} \qquad (7),$$

where parameters ρ, $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$ have to meet the condition: $-\rho\boldsymbol{\beta} = \boldsymbol{\gamma}$, in order to eliminate colinearity between spatially non-lagged and lagged exogenous variables.

There is also a group of generalized spatial Durbin panel models taking into consideration three sources of spatial interactions with fixed effects (GSD-FEM, Generalized Spatial Durbin Fixed Effects Model):

$$y_{it} = \rho \mathbf{W} y_{it} + \alpha_i + \mathbf{x}_{it}^T \boldsymbol{\beta} + \mathbf{W}\mathbf{x}_{it}^T \gamma + u_{it},\ u_{it} = \lambda \mathbf{W} u_{it} + \varepsilon_{it},\ \varepsilon_{it} \sim N(0, \sigma_\varepsilon^2), \qquad (8)$$

or random effects (GSD-REM, Generalized Spatial Durbin Random Effects Model):

$$y_{it} = \alpha_0 + \rho \mathbf{W} y_{it} + \mathbf{x}_{it}^T \boldsymbol{\beta} + \mathbf{W}\mathbf{x}_{it}^T \boldsymbol{\gamma} + v_{it},\ v_{it} = \alpha_i + u_{it},\ u_{it} = \lambda \mathbf{W} u_{it} + \varepsilon_{it};\ \varepsilon_{it} \sim N(0, \sigma_\varepsilon^2) \qquad (9).$$

3. Applications of SDPMs in Migration Analyses

The specialist literature presents numerous versions and variants (see Section 2.3) of econometric models for panel data with spatial interactions (Spatial Panel Econometric Models), including Durbin models (Spatial Panel Econometric Durbin Models). The models have an established position in methodological literature and empirical research. Nevertheless, results of applying those tools in regional analyses of migration are not popularized and studies into migration in cities have not been published yet.

A "classic" spatial panel model (with fixed effects) was used in a study that concerned modelling the volumes of emigration and immigration depending on socio-economic processes occurring in 418 states of North America in the years 1980–2000 (Gebremariam *et al.*, 2012). The specialist literature offers many publications on the uses of dynamic spatial panel models in regional analyses of migration processes in the countries or regions of Europe (*e.g.* Basile *et al.*, 2012, Vakulenko, 2014). In turn, the spatial panel gravity Durbin model was applied by LeSage in 2008 (LeSage, 2008). The tool was used to model causes and directions of population outflow from districts of the USA and Columbia, (LeSage, Pace, 2008, pp. 941–967). For Poland, a study on domestic migrations employing the spatial panel gravity model was performed by Pietrzak (Pietrzak *et al.*, 2012, pp. 111−122). In turn, spatial panel Durbin models described in part 2 of this article (strictly with fixed or random effects) were applied in analyses of migration in regions of Spain by Bunea (Bunea, 2012, pp. 9–30). For states of the USA, a study based on the above-mentioned model was carried out by Sierra and Robledo (Sierra and Robledo, 2013, pp. 9–38). To date, there have been no studies dealing with the modelling of migration processes in cities adopting the spatial Durbin panel models presented in this article.

4. Databank and Results of Analysis

4.1. Databank

The study into the movements of people in European cities was performed based on statistical data obtained from the European Statistical Office. The analysed variable was net foreign migration (NM_{it}) in a given city i ($i = 1,..., 271$) and in a given year t ($t = 2005,..., 2012$), adjusted for the volume of demographic changes[3], per 1000 of the population. Exogenous variables were: unemployment rate (UR_{it}), gross domestic product (GDP_{it}), population density (PD_{it}), total population on 1 January (POP_{it}), crude birth rate (CBR_{it}), death rate (DR_{it}), women per 100 men (WPN_{it}), employment rate (ER_{it}) and activity rate (AR_{it}) in a given city i ($i = 1,..., 271$) and in a given year t ($t = 2005, ..., 2012$)[4].

Net migration is positive when the number of immigrants exceeds the number of emigrants (then, from the point of view of the region's economic development, it is its stimulant) or negative when the number of immigrants is lower than the number of emigrants (then it is a destimulant of development). In an advanced analysis of the structure of net migration, it is difficult to interpret it unambiguously. Values of the phenomenon range from $-\infty$ to $+\infty$ and, additionally, there is usually no con-

[3] In Eurostat it is: "**n**et migration plus statistical adjustment: In the context of the annual demographic balance, Eurostat produces net migration figures by taking the difference between the total population change and natural change; this concept is referred to as net migration plus statistical adjustment. The statistics on 'net migration plus statistical adjustment' are, therefore, affected by all the statistical inaccuracies in the two components of this equation, especially population change. From one country to another 'net migration plus statistical adjustment' may cover, besides the difference between inward and outward migration, other changes observed in the population figures between 1 January in two consecutive years which cannot be attributed to births, deaths, immigration and emigration", http://ec.europa.eu/eurostat/cache/metadata/en/tsdde230 _esmsip.htm (accessed on: 25 May 2015).

[4] The time series was not extended by adding observations for the years 2013–2014 due to a considerable shortage of data in databases. For instance, there is no statistical information about migrations for cities of Germany and the United Kingdom or GDP for all the analysed spatial units.

tinuous tendency (trend) in the level of the variable in time. Therefore, for the sake of analyses (part 4), net migration was transformed as follows: negative variable values (destimulants) were transformed into stimulants, *i.e.* positive values, subjecting them to standardization according to the formula: $NM^{*}_{it} = (1/|NM^{(-)}_{it}|)/1000$ (Antczak, Lewandowska-Gwarda, 2015, pp. 53–80).

4.2. Relationships among Variables and Stationary

Out of socio-economic determinants affecting the occurring migration processes, the determinants were chosen that constituted a set of potential candidates for variables explaining changes in net migration in European cities in the years 2005–2012. Based on the correlation analysis results[5] and neoclassical migration (*pull-push*) theory four exogenous variables were eventually chosen to model net migration: *UR*, *POP* and *CBR*[6].

An integral part of the application of panel models is to examine the stationarity of panel forming variables. The testing of series stationarity employs panel stationarity tests[7]. This study applied the Levin-Lin-Chu test[8] with the following set of hypotheses: H_0: panels contain unit roots and H_1: panels are stationary. Results of the stationarity tests of selected variables forming the panel's series are shown in Table 4.1.

Based on information contained in Table 4.1, it can be stated that both the net migration determinants and the endogenous variable were stationary or stationary around the trend (*lPOP*). Thus, some long-term stability of processes and elimination of spurious regression were observed.

Table 4.1. Results of the Levin-Lin-Chu unit-root test for each variable of the panel

	UR	*lUR*	*POP*	*lPOP*	*CBR*	*lCBR*	*NM*	*lNM*
Time trend not included								
Adjusted t*	0.31	–0.69	–10.4	0.02	–24.3	–13.3	–200.2	–89.3
p-value	0.62	0.25	<0.001	0.51	<0.001	<0.001	<0.001	<0.001
Time trend included								
Adjusted t*	–70.1	–30.5	–56.6	–77.2	–37.2	1.66	–100.3	–90.6
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	0.95	<0.001	<0.001

Source: own elaboration.

5 Correlation matrix is available under the e-mail contact: wiszniewska@uni.lodz.pl.

6 The GDP variable was used in constructing the economic distance matrix ($\mathbf{W}_e$). Hence, in order to avoid the potential colinearity of variables and the issue of matrix endogeneity, the model did not include that determinant in such a form in modelling.

7 http://keii.ue.wroc.pl/przeglad/Rok%202009/Zeszyt%201/2009_56_1_056–073.pdf, accessed on: 19.05.2015.

8 In details *e.g.* http://www.nbp.pl/publikacje/materialy_i_studia/ms311.pdf, accessed on: 19.05.2015.

4.3. Spatial Dependences

The conducted analysis indicates the presence of significant and varied interregional relationships (different for the specific years of the study and type of the **W** matrix), Table 4.2. One of the aims of the study is to answer the question whether the volume of net migration and its determinants showed statistically significant spatial relationships.

An application of both weights matrices: $\mathbf{W}_d$ and $\mathbf{W}_e$ produced statistically significant values of the global Moran's *I* statistic in the most of years of the time span. It means that the space and spatial interactions play role in the values and tendencies of presented phenomena in the analysed European cities.

The statistically significant spatial interactions, stationarity of panel forming series and confirmed correlation of variables are a condition for creating the spatial Durbin panel model (6). The model is used to estimate the impact of socio-economic variables on the foreign net migration level as well as to verify the hypothesis on the occurrence of spatial interactions in that phenomenon in selected 271 European cities. By including spatial effects, we take into account cross-section dependence on contemporaneous or time lagged cross-section (diffusion) interactions in migration processes. In addition, the spatial lags of the dependent and selected independent variables are taken into account in the regression.

Table 4.2. Significance of spatial interactions for selected variables using **W** matrices*

	2005	2006	2007	2008	2009	2010	2011	2012
				$\mathbf{W}_e$ and $\mathbf{W}_d$				
CBR	+	+	–	–	–	+	+	+
lCBR	+	+	–	–	–	+	+	+
UR	+	+	+	+	+	+	+	+
lUR	+	+	+	+	+	+	+	+
POP	+	+	–	+	+	+	+	+
lPOP	+	+	+	+	+	+	+	+
NM	+	+	+	–	–	+	+	+
lNM	+	+	+	+	+	+	+	+

Note: "+" means that the Moran's *I* statistics is statistically significant on the level $\alpha \leq 0{,}10$ for both matrixes simultaneously, "–" indicates that the Moran's *I* statistics is not statistically significant on the level $\alpha \leq 0{,}10$ for one of the weight matrix or both of them. More results of explanatory spatial data analysis see in Antczak, Lewandowska-Gwarda (2015).

*$\mathbf{W}_d$ is a weights matrix built based on the distance from the determined geographical centres of specific European cities with a circle radius of up to 420 km; $\mathbf{W}_e$ is an economic distance matrix built based on the analysis of the cities' development – the mean Gross Domestic Product *per capita* in euros in fixed prices of 2005 (averaged for years). A highly-developed city was assumed to be such where the GDP per capita exceeded the value or was equal to the value of the third quartile (computed based on mean GDP levels of all the analysed cities), *i.e.* 30,526 euros *per capita*, more in: Antczak, Lewandowska-Gwarda (2015, pp. 53–80).

Source: own elaboration in OpeGeoDa.

5. Empirical Results

Out of many possible variants of the spatial Durbin panel models, the Spatial Durbin Fixed Effects Model described by formula (6) was ultimately chosen for the net migration analysis[9]. Based on that model, two models taking into consideration spatial relationships in the form of geographical ($\mathbf{W}_d$) and economic ($\mathbf{W}_e$) distance matrices as well as a classical non-spatial model, were constructed.

In the initial form of the Spatial Durbin Fixed Models, it was assumed that net migration is the function of the following variables:

$$NM_{it} = f(CBR_{it}, UR_{it}, POP_{it}, \mathbf{W}\, CBR_{it}, \mathbf{W}\, UR_{it}, \mathbf{W}\, POP_{it}) \qquad (10),$$

where: CBR_{it} – crude birth rate, UR_{it} – unemployment rate, POP_{it} – total population on 1 January, $\mathbf{W}$ – spatial weights matrix (the models used two weights matrices: $\mathbf{W}_d$ – spatial weights matrices of adjacency of small geographical distances of up to 420 km and $\mathbf{W}_e$ – economic distance matrix), $\mathbf{W}\ CBR_{it,}$ $\mathbf{W}\ UR_{it,}$ $\mathbf{W}\ POP_{it}$ – spatially weighted independent variables.

Modelling results are shown in Table 4.3 (the exponential function was used).

The spatial Durbin models describing changes in net migration in European cities are an effective tool aimed at verifying described relationships. The inclusion of spatial effects enhanced the quality of spatial models, whereas modelling results gained a more substantial sense (Table 4.3). *Pseudo*-determination coefficients were, on average, 2% higher than the goodness of fit to empirical data of the non-spatial model. What is more, the Chow spatial effects tests indicated the higher quality of those models as compared to non-spatial models as well as their correctness and usefulness in application in that kind of analyses. Thus, it proved justified to take into consideration spatial interactions in the form of the **W** matrix.

All parameters in the non-spatial model were statistically significant. On the other hand, in spatial models, parameters at the crude birth rate variable and at the weighted total population variable showed statistical non-significance, and thus were excluded from further analysis.

Before drawing economic conclusions based on the received results, it should be reminded that net migration was transformed for the purposes of the study (part 4). It took only positive values. High variable values indicated higher share of immigration, while low variable values reflected higher emigration share.

In spatial models, parameter signs for specific variables were the same, hence it can be assumed that results were stable. It is worth noticing that results of parameter estimations (especially for spatially weighted variables) did not fundamentally differ. A significant difference was observed solely for parameter ρ, which was higher in the SD-FEM $\mathbf{W}_d$ model. Thus, it can be stated that spatial relationships described by spatial weights matrices of the adjacency of small geographical distanc-

[9] The carried out tests verifying the quality and usefulness of the spatial panel Durbin models indicated the highest efficacy of models with the spatially lagged dependent variable and fixed effects. Features of the other spatial panel Durbin models (with spatial autoregression of the random element and with random effects) are available at: wiszniewska@uni.lodz.pl.

Table 4.3. Results of spatial and non-spatial analysis of net migration level in European cities

SD-FEM $_{\mathbf{We}}$ $INM_{it} = \rho \mathbf{W}_{\mathbf{e}} lNM_{it} + \beta_0 + \beta_1 lUR_{it} + \beta_2 lPOP_t + \beta_3 \mathbf{W}_{\mathbf{e}} lCBR_{it} + \beta_4 \mathbf{W}_{\mathbf{e}} lUR_{it} + u_{it}$

parameter	value	t-Student	coef.error	p-value
β_0	–23.09	–4.30	5.37	<0.001
β_1	–2.29	–13.74	0.17	<0.001
β_2	0.31	2.89	0.11	0.004
β_3	4.98	3.23	1.54	0.001
β_4	2.29	5.36	0.43	<0.001
ρ	0.11	9.02	0.01	<0.001

pseudo R^2=0.77; Chow test on fixed effects $F^*(270,1890)=1.16$, $F=16.89$ =>$F>F^*$; normality of residuals: Shapiro-Wilk, W=0.95, p-value=0.34, stationarity of residuals: Levin-Lin-Chu, without time trend H_1 for –52.7 (<0.001), with time trend H_1 for –71.7 (<0.001);

Chow Test on spatial effects: $F_{SAR\text{-}FEM}>F^*$; 4.01>1.95, SD-FEM better than FEM;

SD-FEM $_{\mathbf{Wd}}$ $INM_{it} = \rho \mathbf{W}_{\mathbf{d}} NM_{it} + \gamma_0 + \gamma_1 lUR_{it} + \gamma_2 lPOP_t + \gamma_3 \mathbf{W}_{\mathbf{d}} lCBR_{it} + \gamma_4 \mathbf{W}_{\mathbf{d}} lUR_{it} + u_{it}$

parameter	value	t-Student	coef.error	p-value
γ_0	–22.04	–4.15	5.32	<0.001
γ_1	–2.36	–14.27	0.17	<0.001
γ_2	0.30	2.84	0.11	0.004
γ_3	4.09	2.70	1.52	0.007
γ_4	2.15	5.09	0.42	<0.001
ρ	0.62	13.91	0.04	<0.001

pseudo R^2=0.76; Chow test on fixed effects $F^*(270,1890)=1.16$, $F=15.75$ =>$F>F^*$; normality of residuals: Shapiro-Wilk, W=0.95, p-value=0.34, stationarity of residuals: Levin-Lin-Chu, without time trend H_1 for –52.7 (<0.001), with time trend H_1 for –71.7 (<0.001);

Chow's Test on spatial effects: $F_{SAR\text{-}FEM}>F^*$; 3.99>1.95, SD-FEM better than FEM

Note: the models were estimated by two-step Maximum Likelihood.
Source: own elaboration in RCran.

es of up to 420 km ($\mathbf{W}_{\mathbf{d}}$) were stronger. The positive sign of parameters ρ indicates the clustering of low and high values of net migration in the geographical space. Therefore, there were spatial clusters of cities with similar values of the variable in Europe.

A 1% rise in unemployment rate led to a fall in net migration of about 2.3% *ceteris paribus* (parameter values were similar in both the spatial regression models). A decrease in net migration indicated an increase in emigration, *i.e.* outflow of the population from a given city. Economic migration is currently the predominant form of population mobility. The introduction of the free movement of individuals and opening of labour markets in the European Union makes people more mobile. They migrate in the search of better living conditions. They leave cities where unemployment is on the rise, and thus the socio-economic situation deteriorates.

Ceteris paribus, a 1% rise in total population resulted in a rise in net migration of about 0.3% (parameter values were similar in both the spatial regression models). That means that people were more willing to migrate to cities characterized by higher population concentration. Foreigners most willingly settle in big cities, where it is easier to find jobs and dwellings, access commercial and cultural facilities. Big cities are a promise of a better life.

The significance of spatially weighted independent variables indicates that the net migration level in a given city was also affected by the socio-economic situation of cities defined as adjacent according to specific weights matrices. It is a crucial conclusion as it points to the fact that spatial units influenced one another (not only in respect of the dependent variable). A rise in the crude birth rate, unemployment rate and total population in adjacent cities impacted on a rise in net migration in a studied city (*ceteris paribus*). Parameter values for spatially weighted independent variables in the models did not substantially differ, hence it can be stated that the choice of the weights matrix did not affect the results of analysis.

6. Conclusion

The Spatial Durbin Fixed Models presented in the study are a perfect tool of spatio-temporal data analysis. They enable to analyse complex research issues, considering, at the same time, spatial interactions occurring among studied spatial units. They also allow to include the time factor in spatial analysis.

Based on the conducted study, it was proved that spatial econometrics methods constitute an appropriate tool to analyse migration in European cities as the phenomenon is characterized by spatial autocorrelation. Considering information about adjacency of the studied areas (in the form of two differently defined weights matrices) in the models improved the quality of the econometric model. The significance of parameters ρ confirmed spatial dependences among European cities in the scope of net migration levels. That means that there were clusters of cities in Europe which were more willingly left by the population and those that attracted people by their potential. The received results also confirmed that the sensitivity of parameter assessments (values and signs) to the manner of taking into account spatial relationships (the used spatial weights matrices $\mathbf{W}_d$ and $\mathbf{W}_e$) was low[10]. Substantial differences occurred solely for spatial autoregression parameters.

Moreover, the received analysis results confirm that net migration levels in European cities were affected by both their development levels and socio-economic situations of adjacent cities. The ensuring of free population flow and opening of labour markets has increased the mobility of the European Union residents. The population more willingly settles in big cities with great potential. On the other hand, the population leaves cities characterized by deteriorating living conditions.

The direction of future research is an attempt at using other tools of statistics and spatial econometrics, including multi-equation models and the Geographically Weighted Regression, in the analysis of migration processes in Europe. It also seems justified to extend the study in the aspect of statistical data and analysed spatial units (*e.g.* for NTS3).

[10] Which confirms the thesis by, among others, Anselin and Pace (2014, pp. 217–249) about the non-significance of deviations in parameter assessment values influenced by the application of different spatial weights matrices.

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