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Migration Processes in European Cities: A Spatio-Temporal Analysis Using Different Spatial Weights Matrices

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ABSTRACT

The aim of the article is to verify a hypothesis on the occurrence of spatial interactions in foreign migrations in selected European cities by applying different spatial weights matrices that define the multidimensional spatial dependences. The analysis used GIS, ESDA, geostatistical, spatial statistics and econometric tools to recognise and examine these interactions. The main part of the study was a specification of six spatial weights matrices that described relations occurring between cities in different ways: two adjacency and directional adjacency matrices, two geographical distance matrices and economic distance matrix. The study covered 271 European cities in the years 2005-2012. The analysed variable was net migration per 1000 people.

Keywords: Migration Process in Cities, Spatial Autocorrelation, Spatial Weight Matrixes, ESDA, Spatial Statistics.

Procesos migratorios entre ciudades europeas: Un análisis espacio-temporal usando diferentes matrices de pesos

RESUMEN

El objetivo de este trabajo es contrastar el supuesto de interacción espacial entre los inmigrantes no nacionales, en una muestra representativa de ciudades europeas, utilizando un conjunto de matrices de contactos diseñadas para capturar la estructura multidimensional de las dependencias. En el análisis se utilizan diferentes instrumentos de geoestadística espacial, con base GIS, junto a indicadores ESDA y herramientas de econometría espacial. En la primera parte del trabajo se especifican hasta seis matrices de ponderaciones espaciales para conectar las ciudades de la muestra; dos se basan en el criterio de adyacencia, en otras dos se utilizan medidas de adyacencia direccional y las dos últimas están basadas en sendas medidas de distancia económica. El estudio incluye 271 ciudades europeas en los años 2005-2012. La variable analizada es la migración neta por 1.000 personas.

Palabras clave: Proceso de migración en las ciudades, autocorrelación espacial, matrices de peso espaciales, ESDA, estadísticas espaciales.

Classification JEL: O15, C21, C46

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1. INTRODUCTION

The free movement of people in the majority of Europe results 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.

In the 21st century, Europe has become a continent of migration. Between 2001 and 2008, net migration in the European Union was higher even than in the USA; the number of citizens migrating to another Member State rose, on average, by 12% per year. In 2009, migration flows slowed down because of the world economic crisis. The impact of that situation on unemployment has been more pronounced for immigrants than for the native-born; it has also led to hostility against migration in certain social and political groups in host countries (European Urban Knowledge Network, 2012). Many people, especially citizens of the European Union, returned to their native countries to wait for the end of those difficult economic times.

The specialist literature typically considers issues of migration in the context of a country or region, while empirical studies (particularly those using spatial statistics and econometrics methods) rarely are concern with cities.[1] A hundred years ago, only 20% of the world population lived in urbanised areas. At present, that percentage is estimated at over 50%. According to forecasts, it will increase to as much as 70% in 2050.[2] Due to the fact that the current birth rate in Europe is very low (0.212% in 2013),[3] it is migrations that exert the major impact on urbanisation processes.

Rapidly developing European cities attract people from around the world. They are characterised by high levels of both immigration and emigration. Reasons for migration are often very complex. The main factors leading to movements of people include social, demographic, cultural, psychological, environmental, political and economic aspects, which may occur at the same time (Bonifazi, Okólski, Schoorl, Simon, 2008). Most often, however, people move to big cities to acquire education at prestigious universities and get good jobs. A common motive is also the willingness to live in a vibrant city that is a centre of culture and entertainment. Residents of big European cities, particularly the young, with high education levels and command of foreign languages, are currently very mobile, prone to travelling and frequently changing their place of residence. According to estimates, in major European cities such as London,

[1] The specialist literature thoroughly discusses only migration of people from rural areas to cities.

[2] Data published by the Global Health Observatory: http://www.who.int/gho/urban_health /situation_trends/urban_population_growth_text/en/ (Accessed on: 03.08.2014).

[3] Data published by World Population Statistics: http://www.worldpopulationstatistics.com/ europe-population-2013/ (Accessed on: 05.08.2014)

Frankfurt, Amsterdam and Brussels, over 25% of the population are first-generation immigrants (European Urban Knowledge Network, 2012). Thus, migrations greatly influence features of contemporary cities - their size, number of residents and social, cultural, political or economic reality.

One of the main challenges to European cities in the scope of the immigration policy is to integrate different, often very homogeneous, groups of immigrants (standing out due to their different cultures and religions) with the local community (Council of Europe and Eurofound, 2008). The integration of the population is easier when immigrants are provided with legal access to education, work, and (if possible) social and medical care. Therefore, the integration process unfolds faster among citizens of the European Union, as all restrictions concerning stay in another EU country have been eliminated for the majority of them. A problem faced by European metropolises is a large number of illegal immigrants who have not obtained residency and work permits. Those people often gather in specific city districts, forming a type of ghetto and thus isolating themselves from the rest of the community. In 2006, the Congress of Local and Regional Authorities of the Council of Europe, along with the city of Stuttgart and Eurofound, established the European network of Cities for Local Integration Policies for migrants (CLIP). This is a network of 30 European cities working together to support the social and economic integration of migrants, combat social inequalities and discrimination against migrants, create conditions conducive to the peaceful co-existence between migrants and other residents and engender respect for migrants' own cultural identity (Spencer, 2008).

The main objective of this article is to verify a hypothesis on the occurrence of spatial interactions in foreign migrations between selected European cities. Migration processes are multidirectional. They can occur over very small as well as long distances and can be characterised by a diverse strength over time. They are also affected by many social and economic factors. Therefore, the first detailed aim of the study is to build several spatial weights matrices that can describe multidirectional and multi-level relations between European cities in different ways. The next purpose is to analyse spatial relations in foreign migrations based on each matrix and to compare the results in detailed. That will enable to identify cities which strongly affect migration processes by attracting people and also generating benefits in neighbouring cities (in addition to the specific matrix W). The last objective of the study is to test the usability of these spatial weights matrices in econometric models and to point out the more effective matrices that reflect spatial interaction the best way.

The study consists of six parts. The first is an introduction to the issues of foreign migrations in European countries. The second is a short review of the research into migration processes based on the specialist literature. The third section discusses the statistical databank that was used by the study. It also presents preliminary statistical data analysis performed with GIS tools. The fourth part presents methods applied in the analysis of migration - global and local Moran's *I* statistics and spatial cross-regressive models. It also thoroughly discusses the process of building all of the spatial weights matrices developed for the study - three adjacency matrices, two geographic distance matrices and an economic distance matrix (the process of constructing weights matrices used a number of spatial statistics tools which allowed the identification of spatial trends and the heterogeneity of the studied phenomenon). The fifth part of the paper discusses in detail and compares the results of the analyses of spatial relationships in foreign migrations in European cities obtained by using differently defined spatial weights matrices (the study applies global and local Moran's *I* statistics). The next step is an attempt at constructing spatial econometrics models. Based on the obtained estimation results, differences occurring as a result of using specific weights matrices are identified. The sixth part sums up the article and describes the directions of further research.

The study covered 271 European cities in the years 2005-2012. The analysed variable was net migration per 1000 people.

2. THE ANALYSIS OF MIGRATION PROCESSES IN THE LITERATURE - EXAMPLES OF STUDIES

The phenomenon of migration is intensifying in Europe. Many countries are both the source and destination of migration. Therefore, issues connected with the causes, effects and directions of population flows are a frequent topic of political and academic discussions. Nevertheless, the specialist literature offers few empirical analyses based on statistical data regarding population flows in European cities using spatial statistics and econometrics tools.

Analyses of net migration in European cities applying spatial methods similar to the present one were discussed, among others, in publications by G. Scardaccione et.al (2010) entitled *Spatial Autocorrelation Analysis for the Evaluation of Migration Flows: The Italian Case* and B. Murgante and G. Borruso (Murgante, Borruso, 2012) entitled *Analysing Migration Phenomena with Spatial Autocorrelation Techniques*. These studies verified spatial relationships with respect to the numbers of foreigners as compared to the total number of residents in Italian urban centres. The studies, however, were carried out without considering international flows (the number of foreigners was explained by directional migrations from other European countries rather than cities).

The specialist literature offers many publications presenting the results of research into migration processes in cities, disregarding, however, the issue of interregional relationships. For instance, a 2009 article by M. Zimmer raises the issue of suburbanisation of Vienna as a result of internal migrations (Zimmer, 2009). Moreover, this publication provides an extensive review of the literature on modelling positive and negative effects of the depopulation of cities (using, among others, the GWR).

In turn, the results of analyses of the determinants and effects of migrations performed at administrative levels higher than cities and using quantitative (non-spatial) methods were presented articles such as one by P. Nijkamp and K. Spiess from 1995 (Nijkamp, Spiess, 1995). Furthermore, a 2007 study by N. Bailey and M. Livingston offered the results of their research into the impact of migration processes on the developmental level of the target region, units of origin and neighbouring units in England and Scotland (Bailey and Livingston, 2007). In turn, in 2011, a paper was published in which V. Martinho presented results of net migration analysis in regions of Portugal (Martinho, 2011).

The specialist literature also offers numerous articles presenting the results of studies applying ESDA and spatial econometrics tools in research into migration processes. For example, a 2010 study by D. Tsegai and Q. Le Bao discussed determinants of migration flows as well as spatial distribution of and differences in migration in Ghana (Tsegai and Le Bao, 2010). Additionally, a 2009 publication by D. Chi and G.W. Marcouiller presented results of a similar analysis conducted for regions of the US Lake State of Wisconsin (Chi and Marcouiller, 2009).

3. STATISTICAL DATA - PRELIMINARY ANALYSIS

3.1. Statistical databank

The study into the movements of people in European cities was performed based on statistical data available in the European Statistical Office. The analysed variable was net foreign migration adjusted for the volume of demographic changes[4] per 1000 people in 271 European cities[5] between 2005-2012. The variable was denoted as NM_{it} (net migration). The analyses were carried out on annual data - for each year separately. However, due to the extensiveness of the issue, a variable averaged for years for each city was also introduced: NM_{av}

[4] In Eurostat it is: "**net 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://epp.eurostat.ec.europa.eu/portal/page/portal/population/data/database, in: Demographic balance and crude rates - NUTS 3 regions (demo_r_gind3) (accessed on: 9 July 2014).

[5] This analysis takes into account European cities for which statistical data was available on Eurostat for the entire analysed period.

(average net migration). This kind of transformation is commonly used in economic research based on time series data (see e.g. Mayda, 2007).

Net migration takes positive (when the number of immigrants exceeds the number of emigrants) as well as negative values (when the number of immigrants is lower than the number of emigrants). In the advanced analysis of the structure of a balance, it is difficult to interpret negative values unambiguously. Therefore, for the sake of analyses (Sections 4 and 5), negative net foreign migration values were transformed into stimulants, i.e. positive values, subjecting them to standardisation according to the formula: $NM_{it}^{*} = (1/|-NM_{it}|)/1000$. Thus, initial (raw) negative variable values got positive but appropriately low values. The averaged variable was also standardised and denoted by symbol NM_{av}^{*}.

The process of building the economic distance matrix and econometric modelling also applied statistical information on the Gross Domestic Product in 271 cities in the years 2005-2012.

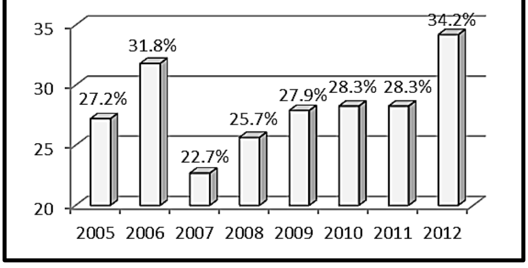
Hence, the statistical database used in the study contained information on net foreign migration (NM_{it}, NM_{av}), standardised net foreign migration (NM_{it}^{*}, NM_{av}^{*}) and GDP in 271 European cities between 2005-2012.

3.2. Preliminary data analysis

European cities are very diverse in their immigration and emigration levels and trends. No consistent increase in net migration per 1000 people[6] was observed in any of the analysed cities in the study period. A drop from period to period was observed only in two cities, Athens and Bucharest. Thus, statistical data did not display a definite upward or downward trend.

Figure 1

Percentage of cities with negative net migration in the years 2005-2012



Source: Own elaboration.

[6] In Section 3.2 of the article, all analyses were performed on raw data, the NM_{it} variable.

In 2007, the percentage of cities with negative net migration was the lowest: at 22.7%. In turn, it was the highest in 2006 and 2012: at 31.8% and 34.2% respectively (see Figure 1).

The maps given below (Figure 2) show changes in the migration processes in European cities during the analysed period. The most marked changes took place in Spain. In 2005 and 2007, Spanish cities were characterised by very high and positive net foreign migration and thus immigration significantly exceeded emigration. In those years, the highest level of the variable in Europe was observed in 5 Spanish cities - Alicante, Malaga, Palma de Mallorca, Santa Cruz de Tenerife and Toledo. After 2008, the situation began to change. In 2010, the value of net migration dropped considerably but most of the analysed cities, apart from Valencia and Murcia, still reported positive variable values. In 2012, the analysed Spanish cities showed negative net migration, with some even being very high (e.g. Barcelona and Valencia). The reason for such a drastic change in the direction of migration was undoubtedly the economic crisis. A similar situation occurred in cities located in Ireland and Greece, where they were characterised by high positive net foreign migration until 2008. Then, the recession made people leave those countries, particularly Dublin in Ireland and Ioanina in Greece in 2010. The maps also show that cities of Eastern Europe (in Poland, Romania, Bulgaria and Hungary) were mainly characterised by negative net migration, i.e. the predominance of emigration, throughout the study period. In the initial period (2005-2007), the highest foreign net migration occurred in the western and southern parts of Europe. In 2010, there was a noticeble stabilisation of the migration processes, especially with respect to immigration. After 2010, people migrated to cities in highly-developed and more economically stable countries, i.e. the United Kingdom, Luxembourg, Germany as well as the northern part of Italy.

Figure 2
Foreign net migration per 1000 people in selected European cities in 2005, 2007, 2010 and 2012

Figure 2 ***(continue)***
Foreign net migration per 1000 people in selected European cities in 2005, 2007, 2010 and 2012

· min; -6 ★ -5,9; -0,51 ★ -0,5; 0,5 ★ 0,51; 12 ★ 12,1; max

Source: Own elaboration in ArcMap 10.2.

4. RESEARCH METHODS

4.1. Moran's *I* statistics

Moran's *I* statistic is a commonly used measure designed for testing the presence of global spatial relationships according to the formula described by the weights matrix **W** (Moran, 1950). For the first time, in 1973, Cliff and Ord demonstrated the vast potential of that statistic, modifying it for the purpose of spatial analyses (Cliff and Ord, 1973). For variable X of observed values x_i in n different regions or locations (i=1, 2,...,n), having weights matrix **W** standardised in rows and original non-transformed observation values, Moran's I statistic is calculated using the similarity measure in the form of cross products of deviations from the mean:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} = \frac{\mathbf{z}^T\mathbf{W}\mathbf{z}}{\mathbf{z}^T\mathbf{z}} \quad (1),$$

where: n – number of observations; x_i, x_j – values of variable x in locations i and j; $\bar{x}$ – mean value of x_i observations; w_{ij} – elements of spatial weights matrix **W**; **z** – vector which takes the form: $\mathbf{z} = \begin{bmatrix} z_1 \\ z_2 \\ \cdots \\ z_n \end{bmatrix}$, where $z_i = x_i - \bar{x}$.

Elements of distance or adjacency matrices are positive integer numbers. This representation of the interactions among spatial observations is, therefore, similar to the use of lags in the time series analysis.[7] If, in a matrix, a large weight reflects a high actual correlation, the value of Moran's *I* statistic is high. If adjacent spatial objects (countries, regions, voivodships, poviats) are similar to one another (i.e. form clusters), the value of the statistic is positive. If objects are different (their spatial distribution is regular, and they do not form clusters), the value of the statistic is negative. In the event there is no correlation between adjacent values, the expected value is close to zero (it is especially noticeable as the number of observations increases). The values for Moran's *I* statistic fall in the $\langle -1;1 \rangle$ interval. It usually reaches values below +/- 1. In order to verify hypotheses concerning spatial autocorrelation (H_0: observed values of the variable are randomly distributed, hence there is no spatial autocorrelation between specific locations, H_1: there is spatial autocorrelation), the so-called randomisation tests are performed.[8]

In turn, local autocorrelation indicates spatial relationships of a given variable in a specific location with its surroundings, i.e. values of that variable in adjacent locations (according to the assumed matrix **W**). Measures for local autocorrelation are *Local Indicators of Spatial Association* (LISA) developed by Anselin (1995). They include the local Moran's I_i statistic. A characteristic feature of those measures is that the sum for all locations is proportional to the value of the global autocorrelation measure $\Sigma_i L_i = \gamma M$. By indicating statistically significant clusters of similar values in adjacent locations, the local statistic of spatial autocorrelation will allow, among others, the evaluation of assumptions of stationarity, i.e. provide a more detailed insight into the structure of spatial distribution of the studied variable in European cities when investigating net migration. It will enable one to recognise not only local autocorrelation, but also heterogeneity patterns as well as identify areas of non-stationarity, outliers, clusters of high and low values and homogenous sub-areas (spatial regimes), and decompose the global measure into parts concerning specific locations. The spatial structure of migration, an important interacting influence on economic and demographical processes, can be analysed in detail by using spatial autocorrelation statistics, such as Moran's *I* indicators.

One of the more common and current spatial analysis issues in the specialist literature is to precisely identify and define what is represented by specific matrix **W** elements.[9] The problem arises from the key feature of the matrix, i.e. exogeneity - an *a priori* reflection of knowledge (Getis and Aldstad 2004, p. 148) of spatial relationships of a random variable (net migration in this case). The specification of spatial weights matrix elements is usually a subjective de-

[7] Antczak (2013).

[8] For the algorithm of this test, see e.g.: Anselin and Bera (1998); Ertur and Le Gallo (2003).

[9] Le Sage (2014), https://www.gate.cnrs.fr/IMG/pdf/Lesage2014.pdf, accessed on: 9 July 2014.

cision of the researcher. In the current literature, scientists take on the challenge of solving the dilemma of construction and selection of spatial weights matrices according to scientific problem (see: LeSage, 2014; Cheng *et al.*, 2014; Piribauer and Fischer, 2013; Bhattacharjee *et al.*, 2011; Chi and Marcouiller, 2010).

In order to characterise the spatial structure of (foreign) migration processes in selected European cities, several matrices of spatial relationships were built (adjacency matrices, geographic and economic distance matrices), based mainly on factual justifications. However, during the process of the precise selection of weights' values or elements of matrix **W, the** methods and techniques of point data analysis within spatial statistics and geostatistics were also applied, including trend surface (spatial) analysis - TSA, standard deviational ellipse and correlogram analysis.

4.2. The choice of the spatial weights matrix

4.2.1.Spatial Contiguity Weights Matrices

$\mathbf{W_1}$ **–** *k-nearest countries*, the weights matrix built based on adjacency of five nearest regions (following the rule of the longest physical length of a region's border). In this case regions are understood as countries as the analysis concerns net migration excluding internal migrations, hence, NOT within the region of origin.[10] The results contained in Part 2 of this paper indicate that migration processes among cities also occur directly off the border of a given country. Thus, the idea behind the weights matrix structure was to take into consideration the nearest adjacency of a given country. The results of this matrix application will indicate cities as the centres attracting emigrants from other adjacent foreign cities.

$\mathbf{W_2}$ **– a** fifth-rank adjacency matrix in the queen configuration taking into account lower-rank adjacencies. Based on statistical data indicating a considerable scale of migration, it can be noticed that, for instance, most Poles migrated to distant countries, including the United Kingdom and Ireland,[11] thus crossing four borders of different countries. Similarly, holiday trips from Poland were mostly to Germany, the Czech Republic, Italy, Croatia or Spain.[12] On the other hand, Poland is usually visited by Spaniards, Germans, Italians and Bulgarians, which also highlights the importance of direct and indirect interregional relationships in Europe.

[10] We calculated that in Europe the average number of the nearest neighbours is approximately 5. More about that kind of matrices in: Cliff A. D., Ord J.K. (1969), Suchecki B. (ed.) (2010).

[11] Most Poles emigrate to the UK (637,000), Germany (500,000) and Ireland (118,000), http://stat.gov.pl/cps/rde/xbcr/gus/L_Szacunek_emigracji_z_Polski_lata_2004-2012_XI_2012.pdf, accessed on: 6 July 2014.

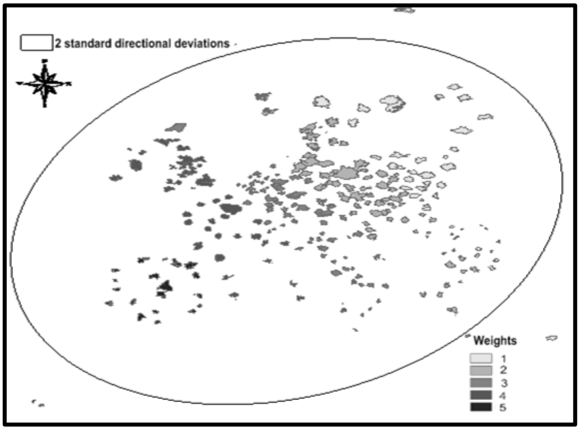
[12] http://www.intur.com.pl/statystyka.htm, accessed on: 6 July 2014.

The significance of the identified spatial lags in matrices $\mathbf{W_1}$ and $\mathbf{W_2}$ is confirmed by results of the spatial structure analysis of the studied phenomenon (Figure 4, section 4.2.2). The calculated correlogram reveals that the statistically significant spatial relationships that characterise net migration in European cities occur up to the distance of approximately 600 km (i.e. in first- and second-rank adjacencies), from 793 km to 914 km (third-rank adjacency) and from 2035 km to 2600 km (fourth- and fifth-rank adjacencies).

$\mathbf{W_3}$ **–** an asymmetrical directional fifth-rank adjacency matrix taking into account lower-rank adjacencies, in which the weights' values were initially determined based on the slope (orientation) of the standard deviational ellipse (Figures 3 and 4), and then made more precise and confirmed by assessments of the parameters of the spatial trend model (TSA), Formula 2.

Figure 3

Spatial trend approximation and ellipse of two standard deviational distributions



Source: Own elaboration in ArcGIS 9.3.

It can be inferred from Figure 3 that the directions of the intensity of migration processes in Europe are: south-west and north-east. The flattening of the ellipse of two standard deviations (which contains 95% of observations),[13] indicates a certain spatial trend in net migration to European cities, which is made more precise and confirmed by statistically significant assessments of surface trend model parameters. The dependent variable in the estimated trend model was net migration in European cities averaged for years. The form of the model is given by the following formula:

$$NM^{*}_{av.} = \beta_0 + \beta_1 X_{coor} + \beta_2 Y_{coor} + \varepsilon_{it} \qquad (2),$$

[13] For the formula and detailed descriptions, see Mitchell (2005).

where: $NM^{*}_{av.}$ – averaged values of net migration per 1000 of the population; X_{coor}, Y_{coor} – standardised geographic coordinates of the centres of the analysed European cities; β_0, β_1, β_2 – structural parameters of the model; ε_{it} – random component.

Upon the assessment of parameters, the model took the following form:

$$\begin{array}{cccc} \hat{NM}^{*}_{av.} = 8.9 & -\,4.87X_{coor} & -\,3.69Y_{coor} & \\ t \quad (8.59) & (-4.35) & (-2.35) & \\ S(b_j) \quad (0.95) & (1.12) & (1.07) & \end{array} \tag{3}$$

All estimated parameters of Model 3 were statistically significant at the assumed significance level of $\alpha = 0.05$ (for critical value $t^* = 1.65$), which confirmed the presence of a surface trend in net migration in Europe. Furthermore, the global spatial average trend in the volume of the phenomenon was upward in the years 2005-2012 ($\beta_0 = 8.19$). Signs of assessed parameters at the X and Y coordinates were negative (-4.87 and -3.69 respectively). This indicated a downward spatial trend in the west-east and south-north directions (confirmation of the initial assumptions read off the standard deviational ellipse, Figure 3). Therefore, cities in western and southern Europe were characterised by a higher level of the analysed variable and there was a downward trend among cities in the eastern and northern parts of Europe. Based on the obtained information about spatial trends in the average level of net migration in European cities in the years 2005-2012, a spatial weights matrix was built. The matrix took into account the occurrence of the spatial trend in such a way that cities in Western and Southern Europe were assigned higher weights, from 3 to 5 (reflecting an upward spatial trend, compare: Figure 3), whereas cities in the East and North were assigned lower weights, from 1 to 2. Moreover, while analysing local spatial trends (formula 3), high outliers were observed where net migration exceeded the average for the studied European cities. In matrix $\mathbf{W}_3$ those cities were assigned weights of 6[14]. There were Uppsala, Oslo, Toledo, Luxemburg, Malaga, Palma de Mallorca, Alicante, Roma, Lefkosia and Ioannina.

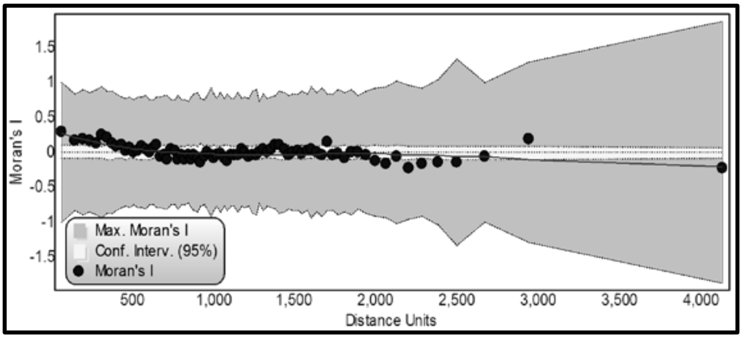
4.2.2. Geographical Distance Spatial Weights Matrices

Geographic distances (from the geographic centres of European cities), which served to build two spatial weights matrices, were selected based on the occurring statistically significant spatial relationships characterising the dis-

[14]The analysis indicated the TSA model defined by Formula 2 as the best under the formal regimes: Jarque-Bera = 5.99 with *p-value* = 0.37, Breusch-Pagan = 3.66 with *p-value* = 0.18 and lower values of Akaike and Schwarz rather than models with high levels of function values.

cussed phenomenon. In order to evaluate the scope of the spatial autocorrelation, a correlogram was drawn showing values of Moran's *I* statistics for specific ranges of distances among the compared locations. The correlogram was made for 40 individual distance ranges, where approximately *I* confidence intervals were computed from 999 simulations (permutations done with the Monte Carlo method), Figure 4.

Figure 4
Moran's *I* correlogram for the separate 40 lags in the entire range of distances (in km) between the analysed locations of $NM^{*}_{av.}$



Source: Own elaboration in SAM.

The data shown in Figure 4 indicate that, for the individual distance ranges, the statistically significant spatial autocorrelation characterising net migration in European cities did not reach further than 4000 km, while the distance between the two most remote of the analysed cities was 5800 km (those were Las Palmas in Spain and Tromsø in Norway). In turn, in three ranges -94-420 km, 793-914 km and 2035-2600 km- the spatial autocorrelation values of the analysed variable displayed a probability below 5%, and hence were statistically significant spatial relationships. The first of the above distance classes showed a positive spatial autocorrelation decreasing with distance (Moran's *I* from 0.22 to 0.10). That points to the presence of a certain concentration of a few leading cities (due to positive net migration or, in other words, the number of immigrants being higher than that of emigrants) whose strength of spatial relationships decreases with distance. This may have been caused by several factors that determine the appeal of a given region, and thus the created concept of regional development of the core and periphery nature. In turn, the two other geographic distance classes (793-914 km and 2035-2600 km) between adjacent cities were characterised by a negative spatial autocorrelation pattern. Therefore, cities located at these distances from one another showed differences in respect of net migration. To sum up, the results of the analysis indicated that migrations might be local (migration processes occurring at small distances up to 420 km) and global in nature – spatial and statistically significant differences in net migration reached up to more than 2600 km. Hence, two geographic distance matrices were built: $\mathbf{W_4}$ **–** a weights matrix built based on the distance from the determined geographic centres of specific European cities with a circle radius of up to 420 km and $\mathbf{W_5}$ **–** where the weights were determined depending on the geographic distance from the geographic centre of a specific city and units contained in a circle with a radius of up to 2600 km.

4.2.3. Economic Distance Spatial Weights Matrix

$\mathbf{W_6}$ – an *economic distance matrix* built based on the analysis of the cities' development. The economic development measure was 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. Thus, the wealthiest cities were strategic places for potential migrants (regardless of its direct or indirect adjacency to the region of origin). "One" was put in the weights matrix for a city where the mean GDP exceeded or was equal to the third quartile. Furthermore, when this city was in the matrix at the intersect with a region with a lower level of this variable, or the same or higher GDP level (as the potential migrant would choose a wealth or even wealthier region). "Zero" was inserted for regions whose GDPs were lower than the third GDP quartile value in European cities, but only when the city was at the intersect with a city characterised by as low or lower GDP per capita in the matrix. The application of this spatial weights matrix indicates units that play an important role in affecting net migration.[15]

The values of the weights in matrices $\mathbf{W_1}$-$\mathbf{W_6}$ were determined in such a way so that their sums in specific rows equalled one. Moreover, $\mathbf{W}_1$ and $\mathbf{W}_4$ matrices will indicate if there are some spill-over effects on the neighbouring units. The $\mathbf{W_2}$, $\mathbf{W_3}$ and $\mathbf{W_5}$ matrices will define spatial interactions excluding the far distance dilemma. Thus, $\mathbf{W_1}$ is the simplest matrix that just put a signal of the nearest spatial interactions into the analysis, the $\mathbf{W_2}$ defines the queen effect of spreading and shipments equally in all directions, $\mathbf{W_3}$ indicates the queen effect of directional spreading and shipments in particular trends, the $\mathbf{W_4}$ takes into account migration processes on relatively close distances and the $\mathbf{W_5}$ describes the effect of migrants' movements on remote distances. Finally, the $\mathbf{W_6}$ matrix

[15] The possible endogeneity problem related to the computed economic weight matrix will not occur in the econometric model. This weight matrix has been made only based on the third quartile of averaged GDP. The matrix does not contain values of this variable, but only the transformed weights of "one" or "zero" components for the neighbouring cities.

emphasises the most economically-developed cities and stresses their role in modelling of net migration level.

Section 5 of the article presents the results of the analysis of spatial interactions and estimations of spatial cross-regressive models using the above spatial weights matrices: $\mathbf{W_1}$, $\mathbf{W_2}$, $\mathbf{W_3}$, $\mathbf{W_4}$, $\mathbf{W_5}$, $\mathbf{W_6}$.

4.3. Spatial Cross-Regressive Model

There are three basic types of spatial regression models. One of them -the spatial cross-regressive model (SLX)- captures spatial dependence by spatial lags in the explanatory variables **WX**. In this case, the spatial lag variables $\mathbf{WX_1}$, $\mathbf{WX_2}$ and $\mathbf{WX_3}$ are incorporated into the standard regression models as the additional regressors. In the regression specification, the same variables may be included in the non-lagged and spatially lagged forms, such as as (Anselin, 2002):

$$\mathbf{y} = \mathbf{X\beta} + \mathbf{WX}\gamma + \boldsymbol{\varepsilon} \qquad (4),$$

where the values of dependent variable y depend on the values of the selected variables x_{ir}, (i=1,...,k) from a given r-region and on the weighted values of the same variables from neighbouring regions [w_{rs}, x_{is}], ($s \neq r$), according to the assumed spatial weights matrix.

The estimation of parameters in the cross-regressive model can be performed as in the standard regression model by OLS. This results from the fact that spatial lag variables share the properties with the original regressors, which are assumed to be non-stochastic.

5. RESULTS OF ANALYSIS

5.1. Spatial interactions in net migration analysis using different W matrices

Spatial relationships/interaction arising from population flows are determined by migration processes. The motives behind migration flows were discussed in the first part of this article, whilst at this stage of the study we seek an answer to the research question of whether the volume of net migration in European cities shows statistically significant spatial relationships. Does the strength of these interactions change with distance or is it determined by other socio-economic factors? Does the application of spatial weights matrices differentiate analysis results, and are they justified and factually correct?

The conducted analysis indicates the presence of significant and varied inter-regional relationships (different for specific years of the study and by the type of **W** matrix), Table 1.

Table 1

Values of global Moran's ***I*** statistics for NM^* and $NM^*_{av.}$ using W matrices

NM^*		2005	2006	2007	2008	2009	2010	2011	2012	$NM^*_{av.}$
W_1	Moran's *I*	0.03	0.01	0.01	0.01	0.05	0.07	0.05	-0.002	0.05 (+)
	p-value	0.01	0.08	0.08	0.11	<0.01	<0.01	<0.01	0.63	<0.01
W_2	Moran's *I*	-0.03	-0.02	-0.04	-0.02	-0.02	-0.02	-0.02	-0.03	-0.02 (-)
	p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
W_3	Moran's *I*	-0.05	-0.03	-0.05	-0.03	-0.01	-0.02	-0.02	-0.03	-0.02 (-)
	p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
W_4	Moran's *I*	0.18	0.09	0.15	0.07	0.0004	0.05	0.07	0.09	0.07 (+)
	p-value	<0.01	<0.01	<0.01	<0.01	0.32	<0.01	<0.01	<0.01	<0.01
W_5	Moran's *I*	0.02	-0.04	0.01	0.002	-0.06	-0.06	-0.01	-0.01	0.001 (+)
	p-value	<0.01	0.55	<0.01	<0.01	0.02	0.02	0.01	0.01	<0.01
W_6	Moran's *I*	-0.002	-0.005	-0.002	-0.002	-0.03	-0.08	-0.09	-0.09	-0.03 (-)
	p-value	0.59	-0.77	0.59	0.68	<0.01	<0.01	<0.01	<0.01	<0.01

Significance level α = 0.05, grey - statistically significant values.

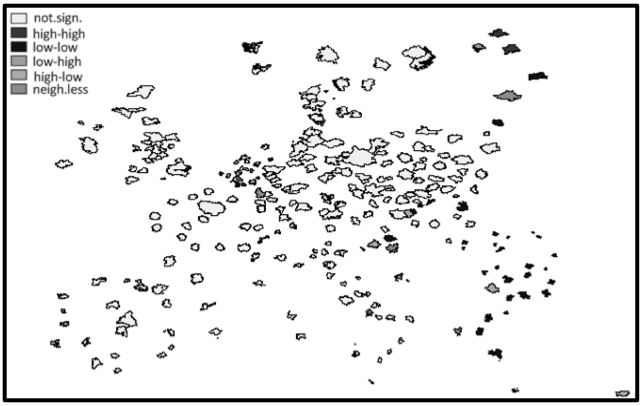
Source: Own elaboration.

When applying spatial weights matrices of the five nearest neighbours (**W_1**), adjacency of small geographic distances (**W_4**) and large geographic distances (**W_5**) for the selected years, positive and statistically significant Moran's *I* statistic values were obtained. This means that in the years 2005, 2009-2011 using matrix **W_1**; in the years 2005-2008, 2010-2012 according to matrix **W_4**; and in the years 2005, 2007-2008 for matrix **W_5**, the cities displayed a tendency to cluster in space with respect to similar net migration levels. Thus, it can be stated that migration also took place at relatively small and large geographic distances, but the strength of those relationships was slight. The values of the statistically significant autocorrelation indices ranged from 0.002 to 0.02, according to assumed matrix **W_5**, and from 0.03 to 0.07 for matrix **W_1**. A stronger relationship characterised net migration for adjacency as defined by matrix **W_4**, as Moran's *I* values ranged from 0.05 to 0.18. The results obtained above were also confirmed by statistically significant Moran's *I* values computed for the variable value averaged for the years $NM^*_{av.}$. On average, stronger positive and statistically significant spatial interactions characterised migrations to cities located close to each other (Moran's $I_{av.}$ = 0.07), i.e. up to 420 km, than in the five nearest neighbouring cities that were selected (Moran's $I_{av.}$ = 0.05), or those as far away from one another as up to 2600 km (Moran's $I_{av.}$ = 0.001).

The values of global spatial autocorrelation are conditioned by local spatial regimes. Fig. 5, 6 and 7 show the local indices of spatial autocorrelation determined based on matrices **W_1**, **W_4** and **W_5**.

Figure 5

LISA results of $NM^*_{av.}$ and W_1



Note: Statistically significant LISA values vary from 0.01 to 0.05, significance maps are available on contact: wiszniewska@uni.lodz.pl; Las Palmas, Santa Cruz de Tenerife and Tromsø are not included on this map (they are not statistically significant). Maps of LISA indices for each year are also available by the above e-mail.

Source: own elaboration.

Positive global Moran's *I* statistic proved the presence of clusters of European cities with similar levels of net foreign migration per 1000 people according to the assumed five nearest neighbours matrix (excluding cities that were regions of origin for a given unit), see Table 1 above and Table 2 below.

Table 2

Examples of cities according to LISA in 2005-2012 and W_1

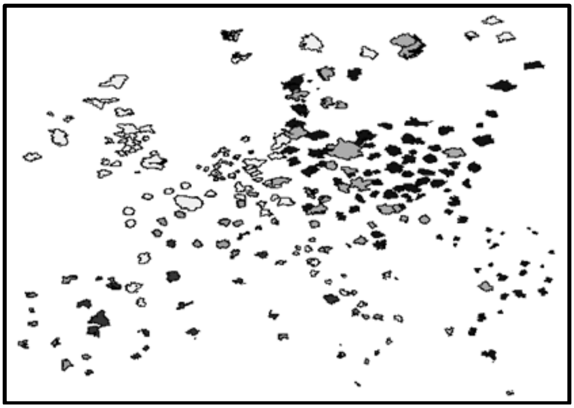
high-high: Finland (Helsinki, Tampere); **low-high:** Portugal (Lisbon, Coimbra, Setúbal), Finland (Turku).	**high-low**: Greece (Sofia, Ioannina), Cyprus (Lefkosia), Slovenia (Ljubljana), Slovakia (Bratislava); **low-low:** Belgium (Namur, Antwerp, Gent), Bulgaria (Plovdiv, Varna, Burgas), Greece (Athens, Larisa), Slovakia (Košice, Prešov, Trnava).

Source: Own elaboration.

The assumed smaller geographic distance matrix $\mathbf{W_4}$ provided a more thorough picture of local spatial relationships in the average net migration in the studied years than the nearest neighbours matrix: Figure 6 and Table 3.

Figure 6

LISA results of $NM^{*}_{av.}$ and W_4



Note: Statistically significant LISA values vary from 0.01 to 0.05, significance maps are available upon contact: wiszniewska@uni.lodz.pl; Lefkosia and Tromsø are not included on this map (they are not statistically significant). Maps of LISA indices for each year are also available by the above e-mail. Legend, see: Figure 5.

Source: Own elaboration.

Table 3

Examples of cities according to LISA in 2005-2012 and W_4

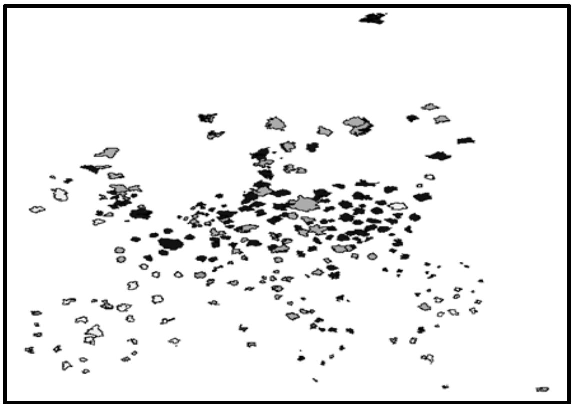
high-high: Spain (Madrid, Valladolid, Toledo, Valencia, Las Palmas), France (Limoges, Toulouse, Toulon), Italy (Turin, Rome, Sassari); **low-high:** Portugal (Porto, Lisbon, Coimbra, Setúbal), Spain (Oviedo, Bilbao, Córdoba), France (Tours, Clerrmont-Ferrand, Orléans, Poitiers, Grenoble, Dijon), Germany (Saarbrücken), Italy (Potenza).	**high-low:** Poland (Warsaw), Bulgaria (Sofia), Austria (Vienna, Graz), Czech Republic (Prague), Germany (Plzen, Berlin, Leipzig, Dresden), Hungary (Budapest, Győr), Slovenia (Ljubljana), Slovakia (Bratislava); **low-low:** Czech Republic (Brno, Ostrava, Olomouc, Pardubice, Zlín), Poland (all apart from Warsaw), Germany (Hannover, Weimar, Erfurt, Magdeburg, Göttingen), Greece (Athens, Thessaloniki, Larisa, Kavala), Lithuania (Kaunas), Latvia (Riga), Romania (Cluj-Napoca, Timisoara, Craiova, Braila, Arad, Sibiu), Hungary (Miskolc, Debrecen, Szeged), Denmark (Aalborg), Slovenia (Maribor), Estonia (Tallinn), Croatia (Zagreb), Bulgaria (Stara Zagora, Varna, Pleven Ruse), Sweden (Jönköping).

Source: Own elaboration.

In the case of the spatial relationships described by the geographic distance matrix $\mathbf{W}_5$ and the initial years of the analysis, positive global Moran's I values were obtained (see Table 1) characterising net foreign migration. This also translated into the positive value of the index determined based on that variable's averaged values as well as the picture of local interregional interactions: Figure 7 and Table 4.

Figure 7

LISA results of $NM^{*}_{av.}$ and W_5



Note: Statistically significant LISA values vary from 0.01 to 0.05, significance maps are available upon contact: wiszniewska@uni.lodz.pl; maps of LISA indices for each separate year are also available by the above e-mail. For the legend, see Figure 5.

Source: Own elaboration.

Table 4

Examples of cities according to LISA in 2005-2012 and W_5

high-high: Spain (Las Palmas, Santa Cruz de Tenerife), Italy (Sassari); **high-low:** Belgium (Antwerp, Gent, Namur, Brussels, Liége), Austria (Vienna, Graz), Bulgaria (Sofia), Germany (München, Köln, Frankfurt am Main, Nürnberg, Leipzig, Dresden, Karlsruhe, Regensburg, Mainz), France (Nantes, Rennes, Toulon), Spain (Murcia), Cyprus (Lefkosia), Czech Republic (Prague, Plzen), Greece (Ioannina), Hungary (Budapest, Győr), Luxembourg, Switzerland (Bern, Zürich, Geneva, Lausanne), Italy (Verona, Reggio di Calabria, Padua, Venice, Turin, Rome, Sassari), The Netherlands (Hague), Poland (Warsaw), Slovenia (Ljubljana), Slovakia (Bratislava), United Kingdom (Bristol, Cambridge, Wrexham, Nottingham, Edinburgh, Scheffield, Newcastle upon Tyne, Aberdeen, Kingston upon Hull, Bradford-Leeds), Sweden (Malmö, Stockholm, Heerlen, Breda, Göteborg, Uppsala, Örbero), Norway (Oslo, Bergen, Stavanger), Finland (Helsinki, Tampere).	**low-low:** Poland (Płock, Koszalin, Łódź, Cracow, Poznań, Gdańsk, Szczecin, Bydgoszcz), Czech Republic (Brno, Ostrava, Olomouc, Liberec, Ceskié Budejovice), Germanty (Stuttgart, Schwerin, Weimar, Erfurt, Augsburg, Halle an der Saale, Magdeburg), Austria (Linz, Salzburg), France (Strasbourg, Rouen, Orléans, Tours, Nancy, Metz, Dijon, Amiens), Belgium (Brugge, Charleroi), United Kingdom (Cardiff, Belfast, Lincoln, Portsmouth, Leicester), Romania (Cluj-Napoca, Timisoara, Arad, Targu Mures), Slovakia (Košice, Prešov), Slovenia (Maribor), Norway (Tromsø), Sweden (Jönköping), Finland (Turku), Italy (Salerno, Campobasso, Catanzaro, Tarnato, Potenza), Hungary (Miskolc, Debrecen, Szeged), Croatia (Zagreb, Split), Lithuania (Riga), Greece (Thessaloniki), Estonia (Tallinn); Denmark (Odense, Aalborg); **low-high:** Portugal (Lisbon), Italy (Cagliari, Turin), France (Lyon, Grenoble), Switzerland (Geneva), Spain (Vigo, Lausanne).

Source: Own elaboration.

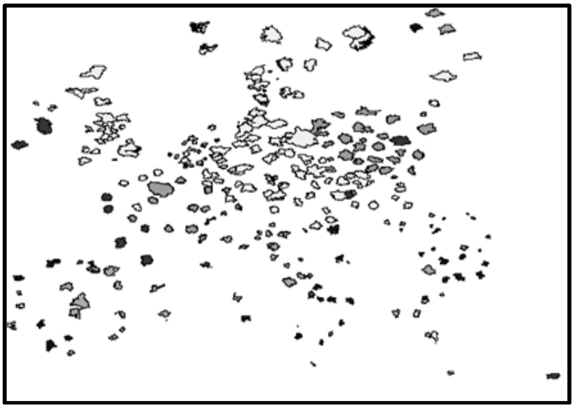
In the subsequent part of the study, the application of matrices $\mathbf{W_2}$, $\mathbf{W_3}$ and $\mathbf{W_6}$ produced statistically significant negative values of the global Moran's *I* statistics (in 2009-2012). This indicates the polarisation of cities with respect to the levels of the analysed variable. In 2009-2012, a negative and moderately strong spatial relationship also characterised cities located at distances of up to 2600 km (absolute values of Moran's *I* statistics range from 0.01 to 0.06), see:

Table 1. Similar values of the index statistics were received for the fifth-rank adjacency matrix and directional fifth-rank matrix (Moran's I statistics for $\mathbf{W_2}$ ranged from 0.02 to 0.04 and 0.01 for the average net migration level; for matrix $\mathbf{W_3}$ the minimum index value was 0.01 and the maximum index value was 0.05; for $NM^*_{av.}$: 0.01). In turn, spatial relationships characterising the levels of the variable in the studied cities according to the assumed economic distance matrix (see Section 4.2.3) were only statistically significant in 2009-2012. On the other hand, those relationships were the strongest (taking into account the absolute values of Moran's I statistics: from 0.01 to 0.09; 0.03 for $NM^*_{av.}$). The examination of spatial autocorrelation based on economic distance allows us to state that units of similar economic potential did not show similarity in the studied area.

Negative global spatial autocorrelation is conditioned by local spatial regimes. Figures 8, 9 and 10, and Tables 5-7 show local indices of spatial autocorrelation determined based on matrices $\mathbf{W_2}$, $\mathbf{W_3}$, $\mathbf{W_6}$ for $NM^*_{av.}$

Figure 8

LISA results of $NM^*_{av.}$ and W_2



Note: Statistically significant LISA values vary from 0.01 to 0.05, significance maps are available upon contact: wiszniewska@uni.lodz.pl; Tromsø is not included on this map as it is not statistically significant. Maps of LISA indices for each year are also available via the above e-mail. For the legend, see Figure 5.

Source: Own elaboration.

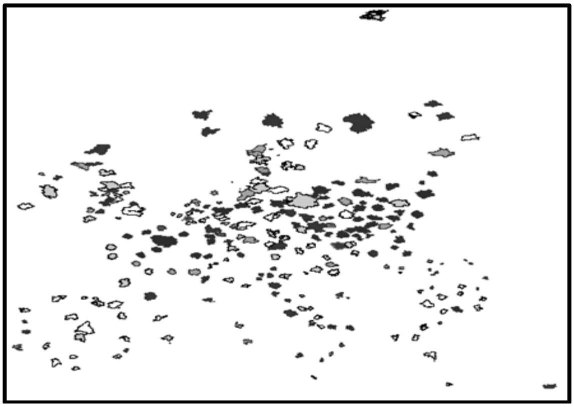
Table 5
Examples of cities according to LISA in 2005-2012 and W_2

high-high: Ireland (Dublin, Cork), France (Bordeaux, Nantes, Rennes, Toulouse, Toulon, Limoges), Poland (Warsaw), Slovakia (Bratislava), Cyprus (Lefkosia); **high-low:** Spain (Madrid, Toledo, Valladolid, Zaragoza, Valencia, Victoria, Barcelona), Italy (Sassari, Rome, Venice, Verona, Cremona, Genoa, Bologna, Modena, Las Palmas, Santa Cruz de Tenerife); Belgium (Gent, Liége), Finland (Tampere, Helsinki), Bulgaria (Sofia).	**low-low:** Bulgaria (Plovdiv, Varna, Burgas, Pleven, Ruse, Stara Zagora), Italy (Salerno, Catania, Catanzaro, Potenza, Terento, Caligari), Croatia (Zagreb, Split), Finland (Turku), Spain (Sevilla, Córdoba, Badajoz, Oviedo); **low-high:** Poland (all except form Warsaw), Frankfurt (Germany), Trnava (Slovakia), Romania (Bacau, Arad, Sibiu), France (Dijon, Nantes, Reims, Paris, Lyon).

Source: Own elaboration.

The application of the directional matrix $\mathbf{W_3}$ (fifth-rank adjacency) produced negative and statistically significant Moran's *I* statistics (in each year of the study and for the average value of the analysed variable, Moran's *I* of $NM^*_{av.}$ = -0.02). Global Moran's *I* statistic values translated into a more precise, than that for $\mathbf{W_2}$, picture of local spatial regimes, Figure 9, Table 6.

Figure 9
LISA results of $NM^*_{av.}$ and W_3



Note: Statistically sign. LISA values range from 0.01 to 0.05, sig. maps are available upon contact: wiszniewska@uni.lodz.pl; Maps of LISA indices for each year are also available via the above e-mail. For the legend, see Fig. 5.

Source: Own elaboration.

The last matrix considered in the spatial analysis of migration processes occurring in European cities was the economic distance matrix ($\mathbf{W_6}$, for description see Section 4.2.3). The application of that type of matrix produced statistically significant relationships for the years selected for analysis (2009-2012), but whose interactions were the strongest (as compared to results for matrices $\mathbf{W_2}$ and $\mathbf{W_3}$, see Table 1). For net migration volumes averaged for years, the negative and statistically significant value of the global Moran's *I* statistic was obtained; the picture of local spatial relationships, taking into account economic potentials, is shown in Figure 10 and Table 7.

Table 6

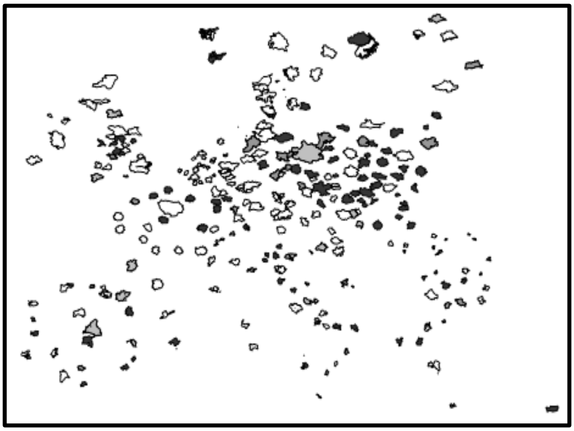
Examples of cities according to LISA in 2005-2012 and W_3

high-high: Finland (Helsinki, Tampere), Sweden (Uppsala, Stockholm), Norway (Oslo, Bergen, Stavanger), United Kingdom (Edinburgh, Aberdeen, Bristol, Cambridge, Wrexham), France (Toulouse), Luxembourg, Germany (e.g. Trier, München, Leipzig, Dresden), Belgium (Brussels), Austria (Vienna), Cyprus (Lefkosia), Czech Republic (Prague), Hungary (Budapest), Italy (Rome, Verona, Cremona, Trento, Perugia, Florence, Bologna, Brescia, Modena); **high-low**: United Kingdom (Exeter, Newcastle upon Tyne, Bradford-Leeds), Ireland (Dublin), Spain (Málaga, Murcia, Palma de Mallorca, Toledo), France (Bordeaux, Nantes, Rennes), Belgium (Antwerp, Gent, Liége, Brugge, Namur), Austria (Graz, Innsbruck), Czech Republic (Plzen), Germany (Berlin, Hamburg, Nürnberg, Karlsruhe, Freiburg im Breisgau, Regensburg), Denmark (Copenhagen, Aarhus), Italy (Venice, Trieste, Ancona, Pescara, l'Aquila, Turin, Genoa, Padua), Sweden (Malmö), Slovenia (Ljubljana); the Netherlands (Hague), Hungary (Győr), Poland (Warsaw), Slovakia (Bratislava), Norway (Tromsø).	**low-low:** Poland (Lublin, Rzeszów, Nowy Sącz), France (Rouen, Orléans, Dijon, Reims), Czech Republic (Brno, Ostrava, Olomouc, Zlín), Hungary (Miskolc, Debrecen), Lithuania (Kaunas), Portugal (Coimbra, Porto), Italy (Palermo, Taranto, Potenza), Germany (Schwerin, Göttingen); **low-high:** Germany (Stuttgart, Bremen), Denmark (Aalborg, Odense), France (Poitiers, Clermont-Ferrand, Lyon), Latvia (Riga), the Netherlands (Amsterdam, Groningen), Czech Republic (Liberec, Hradec, Pardubice), Italy (Cagliari), Poland (Cracow, Poznań), Slovenia (Maribor), United Kingdom (Cardiff, Belfast, Lincoln, Glasgow).

Source: Own elaboration.

Figure 10

LISA results of $NM^*_{av.}$ and W_6



Note: Statistically significant LISA values vary from 0.01 to 0.05, significance maps are available upon contact: wiszniewska@uni.lodz.pl; Tromsø is not included on this map as it is not statistically significant. Maps of LISA indices for each year are also available via the above e-mail. For the legend, see Figure 5.

Source: Own elaboration.

Table 7
Examples of cities according to LISA in 2005-2012 and W_6

high-high: Switzerland (Zürich), Cyprus (Lefkosia), Czech Republic (Prague), Germany (Leipzig, Dresden, Berlin), Spain (Zaragoza, Murcia, Málaga, Palma de Mallorca, Toledo, Alicante, Santa Cruz de Tenerife), Greece (Ioannina), Hungary (Budapest, Győr), Italy (Verona, Cremona, Trento, Perugia, Florence, Brescia), Norway (Stavanger), Sweden (Malmö), Finland (Tampere), UK (Wrexham, Sheffield); **high-low:** Spain (Las Palmas, Madrid, Valencia, Pamplona), Germany (Berlin), France (Bordeaux), Finland (Tampere), Italy (Venice, Trieste, l'Aquila, Pescara, Padua), Slovenia (Ljubljana), Slovakia (Bratislava), UK (Newcastle, Exeter).	**low-low:** Germany (Saarbrücken), France (Nancy, Metz, Dijon, Orléans), Italy (Taranto, Potenza, Catanzaro, Palermo), Portugal (Porto, Coimbra), UK (Lincoln, Stoke-on-Trent, Glasgow), Bulgaria (Pleven, Ruse, Vidin), Greece (Larisa, Irakleio), Romania (Sibiu, Giurgiu, Albia, Târgu, Craiova); **low-high:** Bulgaria (Plovdiv, Stara Zagora), France (Strasbourg, Caen), Spain (Córdoba), Croatia (Split), Italy (Catanzaro, Catania), Romania (Arad, Timisoara), Germany (Halle an der Saale, Magdeburg, Bremen, Erfurt), Czech Republic (Karlovy Vary), Estonia (Tallinn), Poland (Szczecin, Bydgoszcz, Białystok), UK (Worcester).

Source: Own elaboration.

5.2. Econometrics modelling of net migration using different W matrices

The statistically significant and factually correct results of the analysis of spatial relationships presented in Section 5.1 were a formal premise for carrying out further research. The next step was a preliminary attempt at building econometric models describing foreign net migration in European cities. The explanatory variable is affected by many social, economic, demographic, cultural and political factors. However, the aim of the modelling was not to specify the determinants of the explanatory variable, but to try and assess the impact of applying different variants of spatial weights matrices ($\mathbf{W_1}$-$\mathbf{W_6}$) on the results of an econometric analysis. Therefore, to describe net foreign migration depending on the spatially weighted GDP value, six simple cross-regressive models were built (each using a different weights matrix). It thus examined whether an increase in economic development in neighbouring cities affects migration processes in a given region. The models took the following form:

$$\ln NM_{av}^{*} = \alpha_0 + \gamma \mathbf{W}_m \ln GDP_{av} + \varepsilon \qquad (5),$$

where: ln – natural logarithm; NM_{av}^{*} – standardised average value of foreign migration in city i in the years 2005-2012; $\mathbf{W_m}$ – spatial weights matrix, $\mathbf{W_m} = \mathbf{W_1}, \mathbf{W_2}, \ldots, \mathbf{W_6}$; GDP_{av} – average GDP value in city i in the years 2005-2012.

Parameters of models were estimated using the OLS method. Received results see in Table 8.

The best fit for the data was obtained for models using matrices $\mathbf{W_4}$ and $\mathbf{W_6}$. A statistically non-significant parameter at variable $\mathbf{W_m}\ln GDP_{av}$ was obtained for the model with geographic distance matrix $\mathbf{W_5}$ (distance up to 2600 km). Models applying the adjacency matrix $\mathbf{W_1}$ (five closest regions) and the geographic distance matrix $\mathbf{W_4}$ (distance up to 420 km) produced a positive γ parameter value. This means that an increase of 1% in GDP in cities defined as adjacent according to the appropriate weights matrices will result in an average rise of 0.92% in net migration in the studied city for $\mathbf{W_1}$ and 2.3% for $\mathbf{W_4}$. In the other cases – for the adjacency matrix $\mathbf{W_2}$ (fifth-rank adjacency in the queen configuration), adjacency matrix $\mathbf{W_3}$ (directional fifth-rank adjacency matrix) and economic distance matrix $\mathbf{W_6}$ – negative γ parameter values were obtained. This means that an increase of 1% in GDP in cities defined as adjacent according to those weights matrices will result in an average fall of 11.46% in net migration in the studied city for $\mathbf{W_2}$, 11.59% for $\mathbf{W_3}$ and 0.04% for $\mathbf{W_6}$. It should be emphasised that positive parameter values were received when applying matrices taking into account the adjacency of cities located short distances from one another. This may indicate the formation of clusters of cities with similar values of the dependent variable in geographic space (see Section 5.1). On the other hand, negative parameter values were obtained when applying matrices in which adjacency was understood in a much broader manner, which may indicate that people willingly migrated to highly-developed European cities, even if they were located far away from their countries of origin.

Table 8

Results of the SLX models' estimation

Model (spatial weights matrix)	α_0	γ	*p*-value
1 (W_1)	-9.39348***	0.921956	0.00775***
2 (W_2)	115.225***	-11.4579	0.00081***
3 (W_3)	115.751***	-11.5896	0.00525***
4 (W_4)	-23.1593***	2.30335	0.00000***
5 (W_5)	201.662*	-20.0585	0.09767
6 (W_6)	2.58653***	-0.04265	0.00009***

Source: Own elaboration.

As a result of using differently defined spatial weights matrices, vastly different parameter estimation results were obtained. Undoubtedly, the research will be continued to improve the quality of the proposed models by extending the set of explanatory variables and comparing them anew.

6. SUMMARY AND FURTHER RESEARCH

Due to the low birth rate in Europe, contemporary cities have to attract migrants if they wish to develop and exist on the economic, social and cultural map of the world. They have to face the pace of migration processes, which undergo substantial changes over the years, and problems with settling immigrants and integrating them.

In summing up the results of the spatial analysis of foreign migration processes in European cities in 2005-2012 using the constructed spatial weights matrices (describing interregional interactions), units standing out with respect to the level of the phenomenon can be seen in Table 9.

Table 9
Cities attracting or losing migrants, impacting net migration (increasing or decreasing it) in neighbouring regions

high-high: Ireland (Dublin); France (Bordeaux, Nantes, Rennes, Toulouse, Toulon and Limoges); Poland (Warsaw); Slovakia (Bratislava); Cyprus (Lefkosia); Finland (Helsinki, Tampere); Spain (Madrid, Valladolid, Toledo, Valencia Zaragoza, Murcia, Málaga, Palma de Mallorca, Toledo, Las Palmas Santa Cruz de Tenerife); Italy (Verona, Cremona, Trento, Bologna, Modena, Venice, Padua, Rome, Genoa, l'Aquila, Pescara, Turin, Rome, Sassari); Norway (Stavanger, Oslo, Bergen); the Czech Republic (Prague, Plzen); Slovenia (Ljubljana); Switzerland (Zürich); Germany (Leipzig, Dresden, Berlin, München, Nürnberg, Karlsruhe, Regensburg); Greece (Ioannina); Hungary (Budapest, Győr); Sweden (Malmö, Uppsala, Stockholm); Bulgaria (Sofia); the United Kingdom (Exeter, Newcastle upon Tyne, Edinburgh, Aberdeen, Wrexham, Bristol, Cambridge, Bradford-Leeds); Luxembourg; the Netherlands (the Hague); Belgium (Brussels, Antwerp, Gent, Namur, Liége); Austria (Vienna, Graz).	**low-low:** Bulgaria (Plovdiv, Burgas, Pleven, Ruse, Stara Zagora); Italy (Varna, Salerno, Catania, Catanzaro, Caligari, Palermo, Taranto, Potenza; Crotaria (Zagreb, Split); Finland (Turku); Spain (Córdoba, Oviedo); Poland (Lublin, Rzeszów, Nowy Sącz, Cracow, Poznań, Szczecin, Bydgoszcz, Białystok, Płock, Koszalin, Łódź, Gdańsk); France (Rouen, Orléans, Dijon, Reims, Nancy, Metz, Lyon, Clermont-Ferrand, Poitiers, Tours, Grenoble, Strasbourg); Czech Republic (Brno, Ostrava, Olomouc, Zlín, Pardubice, Liberec); Hungary (Miskolc, Debrecen, Szeged); Portugal (Coimbra, Porto, Lisbon, Setúbal); Germany (Schwerin, Göttingen, Saarbrücken, Stuttgart, Weimar, Erfurt, Halle an der Saale, Magdeburg, Bremen, Frankfurt); Greece (Larisa, Athens, Thessaloniki, Kavala), Romania (Sibiu, Târgu, Craiova, Cluj-Napoca, Timisoara, Arad), Lithuania (Kaunas); Latvia (Riga), Denmark (Odense, Aalborg); Slovenia (Maribor); Estonia (Tallinn); Sweden (Jönköping), Slovakia (Košice, Prešov, Trnava) UK (Cardiff, Belfast, Lincoln, Glasgow).

Source: Own elaboration.

In the studied period, along with increasing distance (the matrix of the nearest five neighbours and small distances vs. the weights matrix for a radius of 2600 km), the spatial autocorrelation value decreased - for the average net migration, Moran's I was 0.05, 0.07 and 0.001 respectively. Thus, distance impacted spatial relationships. The results obtained at this stage of the analyses differ but do not exclude one another - they complement one another depending on the assumed matrix $\mathbf{W}$. The clustering of cities with similar net migration levels was the strongest for the small distances matrix (with a radius of up to 420 km), where Moran's I was 0.07. The positive global spatial autocorrelation was reflected by local spatial regimes. The least information was obtained as a result of applying the five nearest neighbours matrix, the most was based on matrix $\mathbf{W_4}$. In turn, strong local spatial concentration accompanied migration at large distances (up to 2600 km), but only in certain years of the analysis. Based on LISA values, it can be noted that clusters of cities with low net migration were surrounded by units characterised by a similar level of the phenomenon. On the other hand, in terms of the background of those clusters, some cities (mostly in the northern and south-western parts of Europe) stood out as definitely attracting migrants (hot spots and spatial outliers as high-low). In turn, the received negative global Moran's I statistical values for the average net migration in European cities indicated spatial differences among units with respect to the analysed variable and matrices $\mathbf{W_2}$, $\mathbf{W_3}$, and $\mathbf{W_6}$. The value of the above statistic for $NM^{*}_{av.}$ was equal for the spatial weights fifth-rank adjacency matrix and the directional matrix built based on it (Moran's I = -0.02). Moreover, the absolute values of Moran's *I* statistic computed for the analysed phenomenon in specific years were higher for spatial relationships described by matrix $\mathbf{W_3}$, while the LISA statistics' picture was more precise than for $\mathbf{W_2}$. Outliers were included in the high-high or low-low groups. The highest values of Moran's *I* statistics were obtained when applying the economic distance matrix ($\mathbf{W_6}$). This indicates a significant impact of a given city's development level on net migration volume (as well as in its neighbouring units). The results of the analyses performed using matrices $\mathbf{W_2}$, $\mathbf{W_3}$ and $\mathbf{W_6}$ indicate a strong impact of cities located in northern and south-western Europe on high net foreign migration per 1000 people. The lowest, though important for occurring spatial relationships, level of the phenomenon characterised units in central, eastern and southern Europe – and partly also in western Europe. The most precise picture of spatial dependences and local relationships was obtained by including a directional matrix in the analysis that only took into account the statistical significance of Moran's *I* statistics, strength of relationships (absolute values of statistics) and LISA's statistical significance.

The last stage of the analysis was building six cross-regressive models considering specific spatial weights matrices. The obtained results allowed us to state that the application of differently defined weights matrices produced significantly different results of econometric modelling.

The direction for further research will be to develop econometric models describing foreign net migration in European cities in 2005-2012 using matrices $\mathbf{W_1}$-$\mathbf{W_6}$. The models will take into account social, economic, demographic and environmental explanatory variables. The application of, for example, a Geographically Weighted Regression in further analyses will enable the identification of local determinants for population flows in European cities. Further research will also be conducted in order to build spatial weights matrices describing the spatial relationships among European cities and the Moran and LISA indicators as precisely as possible will be reinforced with other techniques of spatial autocorrelation.

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