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SPATIAL CORRELATIONS IN DEMOGRAPHIC PHENOMENA ON THE EXAMPLE OF THE REGION OF WARMIA AND MAZURY IN POLAND

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Annotation
Demographic potential is a significant determinant of the development of spatial units. Quantitative and qualitative descriptions of analyses potential provide vital inputs for development and management at different levels of governance. Methods that support the identification of spatial correlations play an important role in analyses of demographic processes. Spatial statistics are used to evaluate and compare various phenomena based on spatial correlations (autocorrelations). This article analyzes demographic changes (population growth) in the Polish Region of Warmia and Mazury with the use of local Moran's I. This statistic supported the identification of clusters of homogeneous areas and outliers in the studied region. Two homogeneous areas were identified: the Olsztyn Functional Urban Area with the city of Ełk and local instabilities in the proximity of Elbląg and Szczytno urban areas. The analysis did not reveal significant spatial correlations in demographic growth between small urban areas in the Region of Warmia and Mazury and their surroundings.

Key words
region, population growth, spatial correlation, Moran's I

JEL classification: *J1, C1*

1. Introduction

Demographic potential is one of the prime movers behind development at the central, regional and local level. It determines the development of spatial units and unleashes the productive potential of human resources. Demographic potential is a measure of human resource development through the revival of the local population or the inflow of migrants. Effective development policies at various levels of territorial governance cannot be implemented without reliable demographic data (Sobczyk, 2015). The quantitative and qualitative aspects of demographic trends have to be analyzed to promote local development, identify sources of untapped potential and the main barriers to growth, and facilitate the implementation of administrative measures to prevent adverse social and economic phenomena (Kołodziejczyk, 2002).

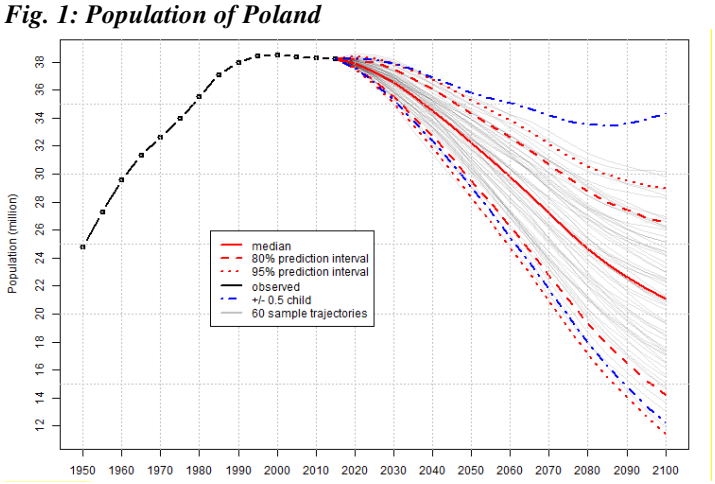
According to Weeks (2004, p. 381), "Demography is an inherently spatial science since it almost always deals with human populations in a defined geographic region, but spatial analysis has thus far played only a small role in the development and testing of demographic theory". Our understanding of demographic phenomena has been expanded by the progress in information technology, including spatial information systems. Spatial methods play an increasingly important role in demographic analyses because demographic phenomena are characterized by spatial trends and autocorrelation. These correlations are investigated with the use of statistical methods to analyze the studied phenomena in view of spatial relationships (Zhang, Ling, 2007). Local and global Moran's *I* are one of the methods for visualizing demographic phenomena. These statistics are frequently used to identify the presence of autocorrelations between the attribute values of spatial objects in various research areas, including in demographic studies at different scales (Carrijo, da Silva, 2017; Miśkiewicz-Nawrocka, Zeug-Żebro, 2017; Laskowska, Dańska-Borsiak, 2016; Lee, Li, 2017; D'Aubigny, 2016; Shen et al., 2016; Podgrodzka, 2014; Chen, 2013; Chi, Zhu, 2008; Tiefelsdorf, 2002; Assuncao, Reis, 1999; Tiefelsdorf , Boots, 1997).

The goal of the study is to determine the spatial dependences in the region in the context of demographic phenomena. In this study, local Moran's *I* was used to determine the presence of correlations between the smallest units of territorial division (municipalities) in the Region of Warmia and Mazury based on the adopted variable of population growth. The areas characterized by spatial variations in terms of population growth were identified in the examined region. Local Moran's *I* was calculated to identify clusters of spatial units characterized by similar values of the adopted variable and to determine the presence or absence of autocorrelations with the neighboring units. The analyzed spatial units are situated in the Region of Warmia and Mazury in north-eastern Poland.

2. Demographic trends in Poland

Poland's population has been declining steadily since 2012, and the country is presently facing a demographic crisis (Sytuacja demograficzna Polski, 2016). The above is confirmed by the projections of negative population growth developed for Poland by the United Nations World Population Prospects 2017 (Fig. 1). Negative population growth is presently observed in most European countries.

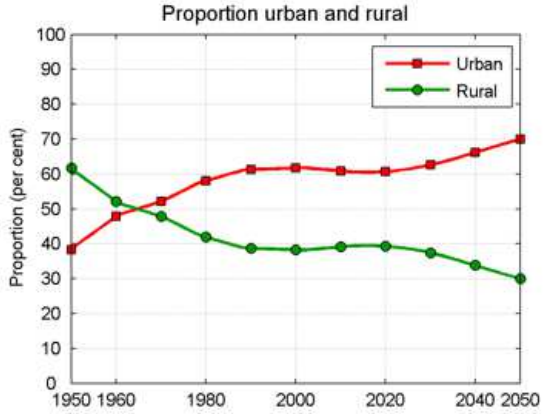
Fig. 1: Population of Poland



Source: United Nations, Department of Economic and Social Affairs, Population Division (2017): World Population Prospects: The 2017 Revision.

Changes in the proportions of urban and rural populations are yet another characteristic demographic trend in Poland. The observed changes have intensified after Poland's political transformation when vast numbers of rural residents began migrating to urban areas. According to the World Urbanization Prospects 2014, the urban population will continue to grow until 2050, which will lead to a steady decline in the rural population (Fig. 2). The greatest population increase will take place in large urban centers, whereas the population of medium-sized and small urban areas will decrease (Prognoza ludności na lata 2014-2050).

Fig. 2: Country profile – Poland. Urban and rural proportions

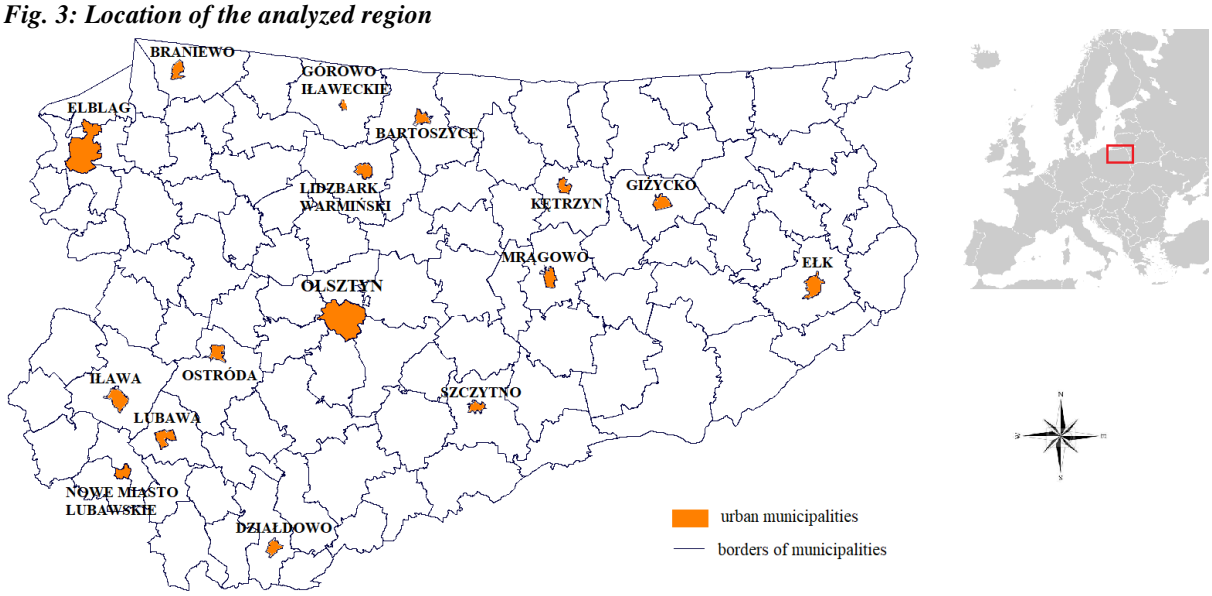


Source: United Nations, Department of Economic and Social Affairs, Population Division (2014): World Urbanization Prospects: The 2014 Revision.

2.1 Spatial variations in demographic processes in the Region of Warmia and Mazury

The demographic trends at the national level are similar to those noted at the regional and local level. The Region of Warmia and Mazury, one of the 16 administrative regions in the country, is situated in north-eastern Poland (Fig. 3). It spans an area of 24,173 km^2 and accounts for 7.7% of Poland's territory. The region has a population of 1,436,367, which represents only 3.7% of the national population (Central Statistical Office, data for 2016).

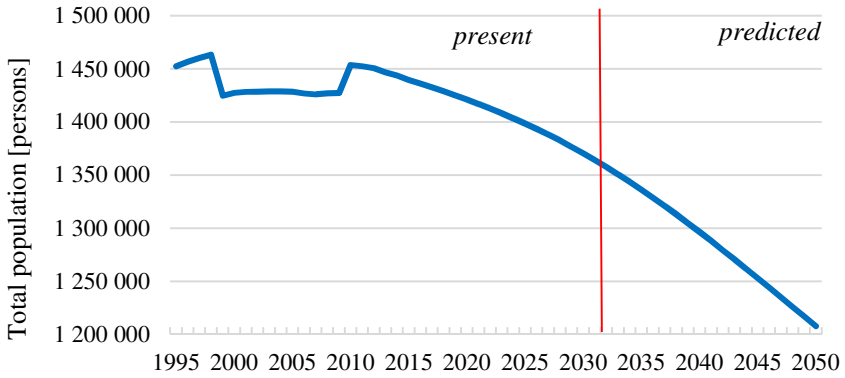
Fig. 3: Location of the analyzed region



Source: own elaboration.

Warmia and Mazury is one of the poorest regions in Poland and the EU, and it is characterized by spatial and developmental peripherality. The predominance of agriculture and high unemployment rates significantly influence the region's demographic processes, in particular population growth and internal and external migration. According to demographic predictions (Fig. 4), a steep and steady population decline is expected in the region in the coming decades.

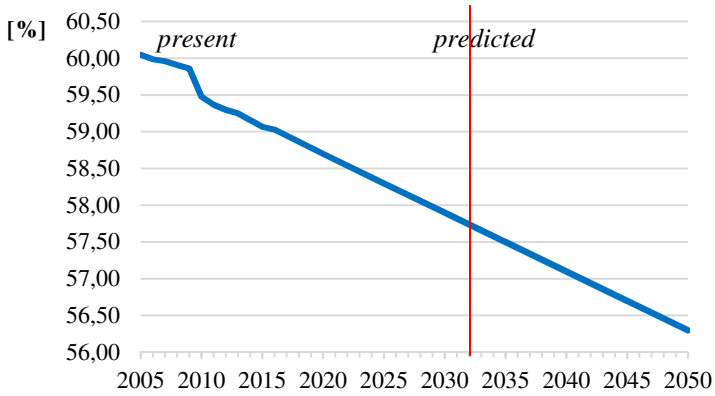
Fig. 4: Region of Warmia and Mazury: population in 1995-2016 and predicted population in 2017-2050



Source: own elaboration based on the Demographic Database of the Central Statistical Office

The analyzed region has 49 urban areas, including 2 cities with a population higher than 100,000, and two cities with a population of 50,000-100,000. The urban areas in the region form 16 urban municipalities, and the remaining areas have mixed urban-rural status. Most towns in the region are small and very small urban centers with a low development potential; nonetheless, they exert an influence on their surroundings. In 2005-2016, the Region of Warmia and Mazury had a relatively high rate of urbanization at around 59-60% (Fig. 5).

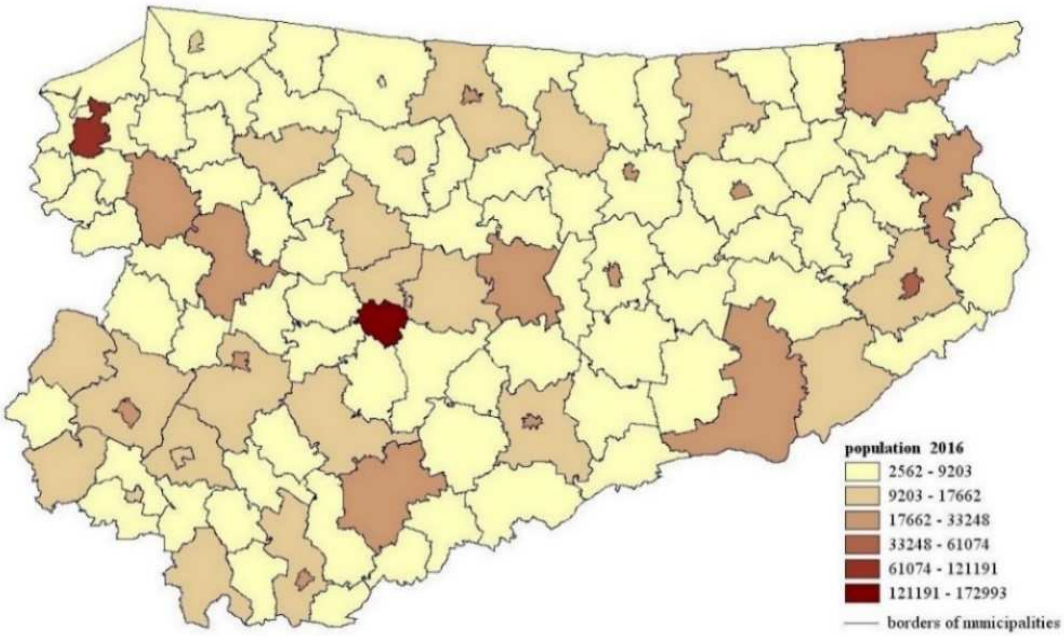
Fig. 5: Rate of urbanization in 2005-2016 and the predicted rate of urbanization in 2017-2050 in the Region of Warmia and Mazury



Source: own elaboration based the Demographic Database of the Central Statistical Office and the Population Forecast for 2014-2050

Despite its predominantly agricultural character, the region had a high urbanization rate of 59.03% in 2016 relative to the national average of 60.18%. Population growth in urban areas peaked in 2007, and it continued to decrease in the following years. In the analyzed period, urban areas had a negative net migration rate until 2011, but this trend has been reversed as of 2012. The spatial distribution of the region's population is presented in Figure 6.

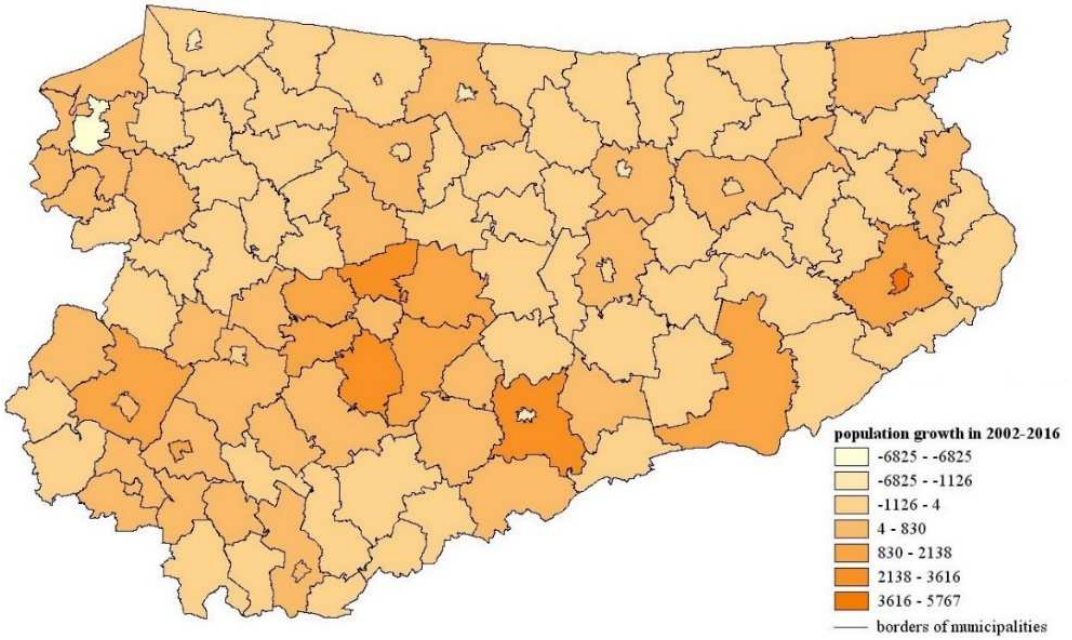
Fig. 6: Spatial distribution of the population in the Region of Warmia and Mazury in 2016.



Source: own elaboration based on the Local Data Bank of the Central Statistical Office

According to the report entitled "The demographic situation of Poland in 2016", suburban areas in the vicinity of large cities (regional capitals, largest sub-regional centers) are the only areas to experience steady population increase, which contributes to growing levels of suburbanization. Population growth was also observed in the areas surrounding Olsztyn, the capital city of the Region of Warmia and Mazury. In contrast, the vast majority of municipalities in the region, including urban and urban-rural municipalities, were characterized by significant population decline in 2002-2016 (Fig. 7). The highest population increase was noted around, rather than within urban centers. The only exception was the city of Ełk which reported the highest population growth in the region. The greatest population decrease in the urban core with a simultaneous population increase in suburban areas were observed in the region's second largest city, Elbląg, and in the city of Szczytno. The city of Olsztyn exerts the greatest influence on the surrounding areas on account of its administrative functions and socioeconomic potential.

Fig. 7: Population increase in the municipalities of the Region of Warmia and Mazury in 2002-2016



Source: own elaboration based on the Local Data Bank of the Central Statistical Office

3. Methodology and Results

The spatial correlations in demographic trends between the municipalities of the Region of Warmia and Mazury were determined with the use of spatial statistics. This approach supports analyses of autocorrelations, namely the spatial relationship of variable values in the evaluated area. Spatial autocorrelations exist when the presence of a given phenomenon in one spatial unit increases or the decreases the probability of that phenomenon occurring in the neighboring units (Janc 2006). Spatial statistics are used to identify the patterns of spatial correlation and spatial heterogeneity. Global and local measures of spatial autocorrelation are applied for this purpose (Antczak, Lewandowska-Gwarda, 2016; Janc, 2006). A spatially and temporary non-homogeneous system is characterized by different values across locations or time intervals (Radło-Kulisiewicz, 2015).

Spatial statistics relies on measures of global and local autocorrelation. Global autocorrelation demonstrates similarities between areas, whereas local autocorrelation provides information on the proximity of the analyzed spatial unit and indicates whether the neighboring spatial units are characterized by high or low values of the evaluated variable.

The local indicator of spatial association (LISA) statistic developed by Anselin (1995) is a measure of local autocorrelation, and Local Moran's *I* is one of such measures. Local Moran's *I* is widely used to test global spatial correlations. According to Anselin, "the local statistic should give an indication of outstanding clustering in either positive or negative spatially distributed regression residuals, and it should point to significant spatial outliers in the regression residuals that do not fit into their surrounding environment" (cited by Tiefelsdorf, Boots, 1997, p. 248). Positive values of local Moran's *I* indicate similarities between clusters of neighboring spatial units. Spatial units that are regularly distributed in space and do not form clusters as well as neighboring units with different variable values produce negative values of local Moran's *I.* In the absence of correlations between neighboring units, the expected value of the discussed statistic approximates zero (Antczak, Lewandowska-Gwarda, 2016; Janc, 2006).

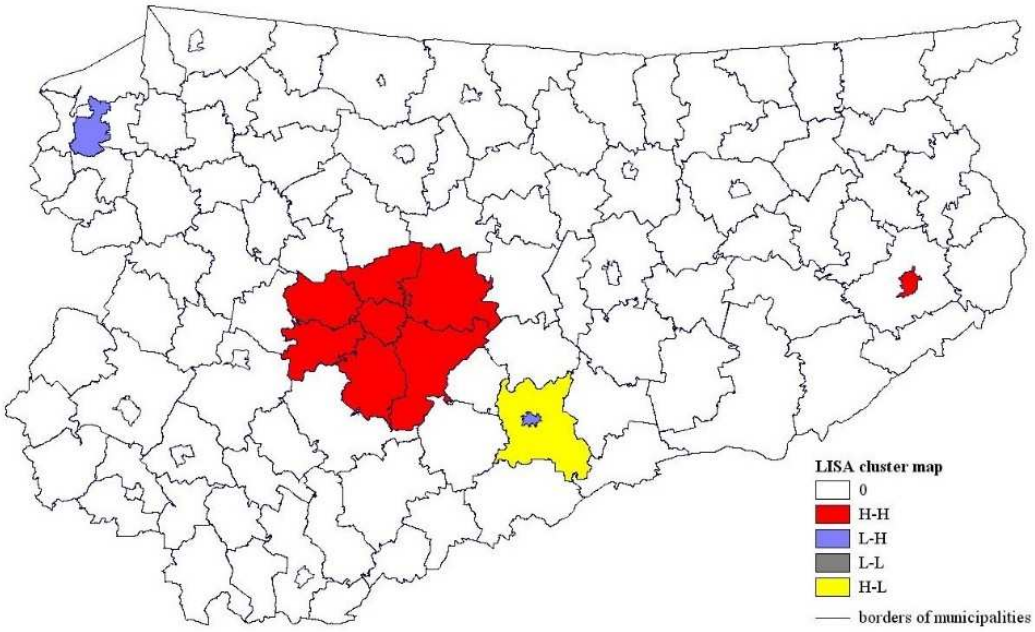
Local autocorrelations are evaluated and interpreted with the use of scatter plots and maps presenting the distribution of spatial units in scatter plot quartiles based on the values of the taxonomic indicator: H-H – high value unit with high value neighbors (1st quartile), L-H – low value unit with high value neighbors (2nd quartile), L-L – low value unit with low value neighbors (3rd quartile), H-L – high value unit with low value neighbors (4th quartile). Local Moran's *I* was calculated based on formula 1 (Więckowska, 2015 citing Anselin, 1995):

$$I_i = \frac{(x_i - \bar{x}) \sum_{j=1}^{n} w_{ij}(x_j - \bar{x})}{\sigma^2} \quad (1)$$

where:
n – number of spatial units,
x_i, x_j – value of the variable for similar objects,
$\bar{x}$ – average value of the variable for all objects,
w_{ij} – elements of the spatial weights matrix,
σ^2 – variance $\sigma^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}$.
A spatial weights matrix with row standardization to 1 was developed based on the boundary lines shared by spatial units.

The results of the analysis are presented in the cluster map of local Moran's *I* statistic (Fig. 8). Spatial correlations between the values of the analyzed variable were noted only in some municipalities in the evaluated region. Most municipalities were not bound by spatial correlations. The municipalities where the local Moran's I was equal to 0 are marked in white in the map.

Fig. 8: Cluster map of local Moran's I statistic for the Region of Warmia and Mazury – population growth in 2002–2016.



Source: own elaboration

In an analysis of population growth, the values of local Moran's *I* reveal two H-H clusters in the analyzed region. H-H clusters denote municipalities with high population growth, which are surrounded by similar spatial units (marked in red). The city of Olsztyn and the surrounding areas (6 rural municipalities) are clearly predominant in the map. The city of Ełk forms a similar cluster. H-L and L-H clusters (outliers) were identified in the rural municipality of Szczytno which surrounds the city of Szczytno (high population growth in rural areas surrounding the city with one of the highest negative rates of population growth in the city of Szczytno). The city of Elbląg also forms an L-H cluster, but population growth in Elbląg's suburban areas was smaller than in Szczytno, whereas the city of Elbląg was also characterized by one of the highest negative rates of population growth. The discussed clusters are statistically significant, and they contribute to local instabilities. Spatial autocorrelations were not determined in the remaining municipalities in the region, which indicates that despite a high number of urban municipalities (urban centers) and urban-rural municipalities, these spatial units does not influence the surrounding areas in terms of their demographic potential.

Conclusions

The cluster map of Moran's *I* statistic presents spatial autocorrelations in demographic trends between the municipalities of the Region of Warmia and Mazury. Local instabilities were observed in the municipalities situated in the proximity of the cities of Elbląg and Szczytno. This is a highly undesirable situation for Elbląg, the second largest urban center in the region which should drive local growth. The Olsztyn Functional Urban Area is

composed of a regional urban center and the surrounding municipalities, and it creates a homogeneous spatial unit with considerable variations in demographic potential. Similar observations were made in Ełk, one of the largest urban centers in the region. The remaining municipalities were not bound by spatial correlations with the neighboring units in terms of population growth. The above applies particularly to urban municipalities which do not have sufficient demographic potential to drive positive population change in their immediate surroundings. For this reason, spatial correlations were not noted in their sphere of influence.

The results of the study could point to a non-continuous development of demographic potential in the analyzed region, which increases the existing disproportions between the city of Olsztyn, its immediate surroundings (accumulation of demographic potential) and other municipalities. Regional management solutions could benefit from the identification of areas where clusters of municipalities are formed based on the values of local Moran's *I*. Clusters of correlated spatial units (municipalities) can be used to identify areas that are homogeneous in terms of the analyzed criteria as well as areas of local instability (outliers) which require special attention. Analyses of spatial trends and correlations provide valuable inputs for regional policy.

Accumulation of demographic potential surroundings the capital of the region and another large cities is observed in relation to other Polish regions (Kłusek, 2017; Kozera, Głowicka-Wołoszyn, 2017; Gołata, Kuropka, 2016; Bartkowiak-Bakun, Standar, 2014; Kołodziejczyk, 2002). Spatial relationships are the strongest in urban functional areas.

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