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The Determinants Of Population Health Spatial Disparities

Abstract

Health of the population is one of the basic factors of social development. The results of empirical studies indicate a number of factors determining the level of health of the population related to access to health care services, the level of environmental pollution and the wealth of society. It must be assumed that the observed disparities in the health depend on distributions of particular determinants. The aim of the article is to assess the significance of the main factors affecting the occurrence of spatial disparities in the level of social development districts NTS-4 in terms of health of the population. The analysis was based on estimates of the Spatial Durbin Model (SDM) which takes into account the impact of neighborhood spatial units on level of dependent variable and the explanatory variables. The size of the level of social development in terms of health of the population in the study was approximate by the aggregate value of the index, which is the local component of the Local Human Development Index LHDI.

***Keywords**: Spatial Durbin Model, population health, Local Human Development Index*

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1. Introduction

Improved health is an important determinant of economic growth as it increases labour productivity, labour supply, educational achievements and savings. (Dahlgren, Whitehead 2007, p. 41). The Constitution of WHO (1946) defines good health as a state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity. Health is determined by many intrinsic (genetics, behaviour, culture, habits and lifestyles) and extrinsic (economic, social, environmental and technological) factors. Determinants combined together affect the health of individuals and communities.

The main aim of this paper is to verify which determinants influence the public health in the investigated and neighbouring regions. The analysis was based on the socio-economic data for poviats (NTS-4 regions).

It was assumed that the occurrence of socio-economic factors (its specific combination) and the intensity of its influence varies spatially. This is related to disparities in the level of socio-economic development. Another aspect considered in research was the importance of interaction of factors influencing health in the neighbouring regions. Due to possibility of occurrence of the three types of spatial interaction, four types of models were estimated and verified.

2. Determinants of population health

The traditional view of the health field is that the art or science of medicine has been the fount from which all improvements in health have flowed, and popular belief equates the level of health with the quality of medicine. Public health and individual care, provided by the public health physician, the medical practitioner, the nurse and the acute treatment hospital, have been widely-regarded as responsible for improvements in health status. Individual health care, in particular, has had a dominant position (Lalonde 1981, pp. 11-12).

Current research confirms that the medical care can prolong survival and improve prognosis after some serious diseases. However, what seems more important for the health of population as a whole are the social and economic conditions that make population be in need of medical care. Nevertheless, universal access to medical care is clearly one of the social determinants of health (Wilkinson, Marmot 2003, p.7).

The Marc Lalonde, the Canadian Minister of National Health and Welfare, in 1974 proposed Health Field Concept which stated that health field can be broken up into four broad elements: (1) human biology, (2) environment,

(3) lifestyle and (4) health care organization. The turning point was to assess the degree of influence of each factor as well as the recognition. Lifestyle was assigned 55% of influence on population health, environmental factors – 20%, human biology was assigned 15%, and health care organization only 10% (Lalonde 1981, pp. 31-34).

The human biology element includes all those aspects of health, both physical and mental, which are developed within the human body as a consequence of the basic biology of man and the organic make-up of the individual.

The environment category contains all those matters related to health which are external to the human body and over which the individual has little or no control. Individuals cannot, by themselves, ensure that foods, drugs, cosmetics, devices, water supply, etc. are safe and uncontaminated; that the health hazards of air, water and noise pollution are controlled; the social environment, including the rapid changes in it, does not have harmful effects on health.

The lifestyle category in the Health Field Concept, consists of the aggregation of decisions by individuals which affect their health and over which they more or less have control.

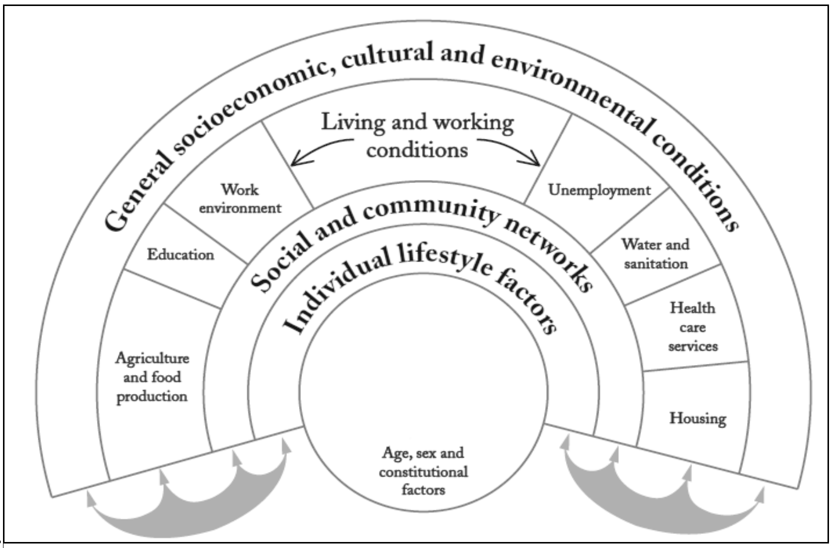
The health care organization is a category which consists of the quantity, quality, arrangement, nature and relationships of people and resources in the provision of health care. It includes medical practice, nursing, hospitals, nursing homes, medical drugs, public and community health care services, ambulances, dental treatment and other health services such as optometry, chiropractics and podiatry. This fourth element is what is generally defined as the health care system. (Lalonde 1981, pp. 31-32).

The determinants of the general health of the population can be conceptualized as rainbow-like layers of influence (Dahlgren, Whitehead 2007, p. 20).

First, there are personal behaviour factors such as smoking habits and physical activity. Second, individuals interact with their peers and immediate community and are influenced by them, which is represented in the second layer. Next, a person’s ability to maintain their health (in the third layer) is influenced by their living and working conditions, food supply, and access to essential goods and services. Finally, as a mediator of population health, economic, cultural and environmental influences prevail in the overall society. This model for describing health determinants emphasizes interactions: individual lifestyles are embedded in social norms and networks as well as in living and working conditions, which in turn are related to the wider socioeconomic and cultural environment.

The determinants of health that can be influenced by individual, commercial or political decisions can be positive health factors, protective factors, or risk factors (Dahlgren, Whitehead 2007, pp. 21-22). The individual genetic susceptibilities to disease may be the common causes of the ill health that affects populations are environmental: they come and go far more quickly than the slow process of genetic change because they reflect the changes in the way people live. (Wilkinson, Marmot 2003, p. 7). Empirical data show that people in a low socioeconomic position experience, on average, more psychosocial stress related to financial difficulties and effort–reward imbalances; they also experience a life or work situation (or both) characterized by high demands and low control (Dahlgren, Whitehead 2007, pp. 26).

Figure 1. The main determinants of health

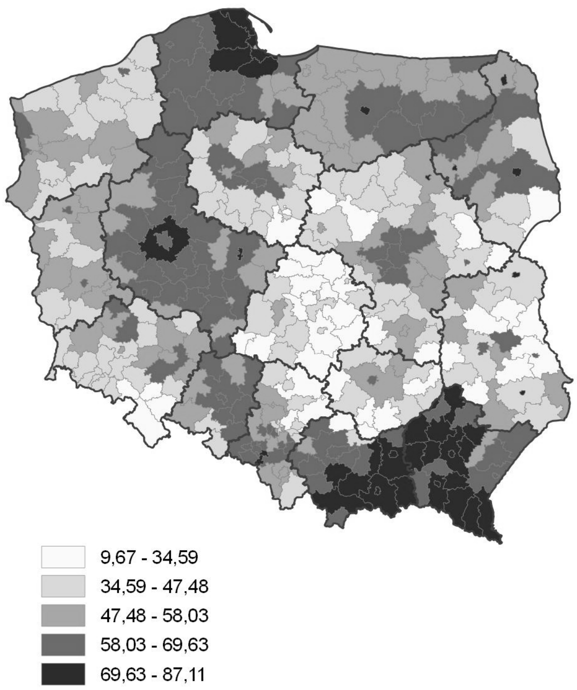


Source: Dahlgren, Whitehead 2007, p. 20.

3. Spatial diversity of population health and its determinants

Original HDI methodology suggests that the measurement of social development should focus on the three essential elements of human life: life expectancy (health), knowledge (education) and the standard, which allows for a dignified life (represented by the level of income - wealth). Health Index, according to methodology presented in the Report on Social Regional and Local Development (UNPD 2012, p. 40) was constructed from two complementary components. The first was the average life expectancy of newborn (from birth) – LEIi (UNDP 2007). The second element of the index was the aggregate rate of death from cancer and heart disease (mortality), as the total number of deaths caused by cardiovascular disease and cancer per 100,000 inhabitants – CDRIi (UNPD 2012, p.104). Calculation of the index required standardization and aggregation of components. The final value of the index represents geometric mean of the two indices normalized with min-max method. (UNPD 2012, pp. 90-91). The opportunity to analyze the factors affecting the health of the population at the county level was limited by the availability of data at (NUTS-4) regional level. The highest value of health index was noted by Podkarpackie, Pomorskie and Małopolskie. At the other extreme there is Łódzkie, with an index value significantly different from the rest of the regions (56% average). Poor performance is also observed in Świętokrzyskie, Dolnośląskie, Śląskie, Lubelskie and Kujawsko-Pomorskie.

Figure 1. Values of Health Index (*HI$_i$*), a factor of Local Human Development Index in 2011, in NUTS4 regions



Source: author's own, based on United Nations Development Programme (2012), *Krajowy Raport o Rozwoju Społecznym 2012, Rozwój regionalny i lokalny*, Warszawa pp. 39-40.

To quantify the impact of each determinant some indicators have been assigned and they are presented in Table 1.

Table 1. Characteristics of health fields determinants

Socio-economic field	
DENSITY	population density [inhabitants per km^2]
H_ED	the share of people with higher education [%]
UEMP	unemployment rate [%]
WAGE	average monthly gross wage [PLN]
RISK	risks associated with the work environment [per 10 thousand inhabitants]
SOCIAL	proportion of people in households benefiting from the social assistance environment in the total population [%]
PRESCHOOL	proportion of children attending preschools (3-5 years old) [%]
SPORT	number of people exercising at sports clubs per 1000 inhabitants
Environment	
WATER	proportion of people using the wastewater treatment plant [%]
CO2	emission of carbon dioxide form plants especially noxious to air purity [per km^2]
SO2	emission of sulphur dioxide form plants especially noxious to air purity
DUST	emission of dust form plants especially noxious to air purity [per km^2]
FOREST	proportion of forest area in total area of poviat
Health care organization	
NURSES	- number of nurses and midwives [per 10 thousand inhabitants]
DOC	- number of doctors (in the main workplace) [per 10 thousand inhabitants]
PH	- number of persons per public pharmacy [inhabitants]
AMBULATORY	- ambulatory health care facility [per 10 thousand inhabitants]

Source: author's own.

4. Methods: Spatial model of population health determinants

Manski (1993) points out that three different types of spatial interaction effects may explain why an observation associated with a specific location may be dependent on observations at other locations:

1. Endogenous interaction effects where the decision of a spatial unit (or its economic decision makers) to behave in some way depends on the decision taken by other spatial units;

2. Exogenous interaction effects where the decision of a spatial unit to behave in some way depends on independent explanatory variables of the decision taken by other spatial units if the number of independent explanatory variables in a linear regression model is K, then the number of exogenous interaction effects is also K, provided that the intercept is considered as a separate variable;
3. Correlated effects, where similar unobserved environmental characteristics result in similar behaviour. (Elhorst 2010, p. 11).

Considering distinction in three types of spatial interaction effects, three basic models of spatial regression should be pointed out.

In the spatial autoregressive model (1) (SAR) values of dependent variables are directly influenced by the values in neighbouring areas.

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

The y denotes an Nx1 vector consisting of one observation on the dependent variable for every unit in the sample (i 1, . . ., N), X is an NxK matrix of exogenous variables, Wy denotes the endogenous interaction effects among the dependent variables, ρ is called the spatial autoregressive coefficient, W is an NxN matrix describing the spatial arrangement of the spatial units in the sample.

In the spatial error model (SEM) the spatial influence comes only through the error terms:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \;\; \boldsymbol{\varepsilon} = \lambda\mathbf{W}\boldsymbol{\varepsilon} + \boldsymbol{\zeta}, \quad \boldsymbol{\varepsilon} \sim \mathrm{N}(\mathbf{0}, \sigma^2\mathbf{I}) \qquad (2)$$

where $\boldsymbol{\varepsilon}$ denotes the vector of error terms, spatially weighted using the W contiguity matrix, λ - spatial error coefficient, $\boldsymbol{\zeta}$ - vector of uncorrelated error terms.

The Spatial Durbin Model (SDM) (5) with a spatially lagged dependent variable (Wy) or spatially lagged error term ($\lambda\mathbf{W}\boldsymbol{\varepsilon}$), and spatially lagged independent variables (WX) has been introduced by Anselin (1988) and is labelled the spatial Durbin model. It is the result of combination of model of SAR or SEM with the spatial cross-regressive model SCM.

Spatial Cross-regressive Model (SCM)

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{W}\mathbf{X}\boldsymbol{\gamma} + \boldsymbol{\varepsilon}, \;\; \boldsymbol{\varepsilon} \sim \mathrm{N}(\mathbf{0}, \sigma^2\mathbf{I}) \qquad (3)$$

Spatial Durbin Model (lag)

$$\mathbf{y} = \rho\mathbf{W}\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \mathbf{W}\mathbf{X}\boldsymbol{\gamma} + \boldsymbol{\varepsilon}, \quad \boldsymbol{\varepsilon} \sim \mathrm{N}(\mathbf{0}, \sigma^2\mathbf{I}) \tag{4}$$

Spatial Durbin Model (error)

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{W}\mathbf{X}\boldsymbol{\gamma} + \boldsymbol{\varepsilon}, \ \boldsymbol{\varepsilon} = \lambda\mathbf{W}\boldsymbol{\varepsilon} + \boldsymbol{\zeta} \quad \boldsymbol{\varepsilon} \sim \mathrm{N}(\mathbf{0}, \sigma^2\mathbf{I}) \tag{5}$$

One strength of the spatial Durbin model is that it produces unbiased coefficient estimates also if the true data-generation process is a spatial lag or a spatial error model. The other one is that it does not impose prior restrictions on the magnitude of potential spatial spillover effects. In contrast to other spatial regression specifications, these spillover effects can be global or local and be different for different explanatory variables (Elhorst 2009, p.11).

To verify the significance of determinants influence on the level of population health, and its spatial dependence the analysis was divided into several steps.

First, the initial equation of regression model (based of cross-secional data for NUTS-4 regions) was specified. This standard approach aims to start with a non-spatial regression model to test whether or not the model needs to be extended with spatial interaction effects. This is known as the specific-to-general approach. Even though the OLS (ordinary least squares method) model in most analysis is rejected in favour of a more general model, its results often serve as a benchmark (Elhorst 2010, p. 11).

The initial equation model estimated by OLS took the following form:

$$\begin{aligned}\ln(HI_i) = {} & \alpha_0 + \alpha_1 \cdot \ln(DENSITY_i) + \alpha_2 \cdot \ln(H\_ED_i) + \alpha_3 \cdot \ln(PH_i) + \\ & + \alpha_4 \cdot \ln(DOC_i) + \alpha_5 \cdot \ln(AMBULATORY_i) + \alpha_6 \cdot \ln(UEMP_i) + \\ & + \alpha_7 \cdot \ln(RISK_i) + \alpha_8 \cdot \ln(PRESCHOOL_i) + \alpha_9 \cdot \ln(WAGE_i) + \\ & + \alpha_{10} \cdot \ln(CO2_i) + \alpha_{11} \cdot \ln(SO2_i) + \alpha_{12} \cdot \ln(WATER_i) + \\ & + \alpha_{13} \cdot \ln(DUST_i) + \alpha_{14} \cdot \ln(FOREST_i) + \alpha_{15} \cdot \ln(SPORT_i) + \varepsilon_i\end{aligned} \tag{6}$$

In the matrix notation the model took the formula:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \ \boldsymbol{\varepsilon} \sim \mathrm{N}(\mathbf{0}, \sigma^2\mathbf{I}) \tag{7}$$

where y denotes an Nx1 vector consisting of one observation on the dependent variable for every unit in the sample (1,…, N), X denotes an NxK matrix of exogenous explanatory variables. In subsequent re-estimations the equation of model was reduced by insignificant explanatory variables.

The starting point for the application of spatial models was the verification of the presence of spatial autocorrelation of error term of preliminary estimated OLS regressiom. One of the basic methods is to test the statistical significance of global spatial autocorrelation coefficient Moran's I. The rejection of the null hypothesis of Moran's I test for spatial autocorrelation in residuals from an estimated linear model evidences that the error term of the estimated model is characterized by spatial interaction defined on the basis a'priori chosen spatial weights matrix.

The most vital in this concept is the definition of a neighborhood set for each location. This is obtained by specifying for each location i (as the row) the neighbors as the columns corresponding to non-zero elements in a fixed (non-stochastic) and positive N by N spatial weights matrix W. The elements of the weights matrix are non-stochastic and exogenous to the model. The Moran's I test statistics as well as the construction of the following spatial models was based on a spatial row-standardized matrix generated on a first contiguity matrix in the queen configuration, which means that two regions are neighbors in this sense if they share any part of a common border.

Next stage, after test of the spatial autocorrelation of residuals was verifying whether the spatial autoregressive model or the spatial error model is more appropriate to describe the spatial distribution of modelling data. For this purpose, the classic LM-tests proposed by Anselin (1988) was used and the robust LM-tests proposed by Anselin et al. (1996). Both the classic and the robust tests are based on the residuals of the OLS model (Suchecki 2010, pp. 302-303). It is assumed that if OLS model is rejected in favour of the spatial lag, the spatial error model or in favour of both models, then the spatial Durbin model should be estimated (Elhorst 2010, p. 18).

4. Results

The results (presented in table 2) show a Moran's I statistic of respectively 0.395, which are highly significant and reject the null hypothesis of uncorrelated error terms. The values of Lagrange Multiplier Test and Robust Lagrange Multiplier Test and its empirical level of significance allowed to reject spatial error model in favour of the spatial autoregressive model. It means that a model with spatially lagged values of health index better described spatial diversification of population health in poviats than a model with spatially lagged factors (and its speciffications) not accounted in the model. Comparison of log likehood (maximum value) and the value of Akaike information criterion (minimum value) let to conclude that the most appropriate model to describe spatial interactions of the dependent variable and the explanatory variables was the spatial Durbin (autoregressive) model.

The introduction of spatial effects for OLS resulted in the loss of significance of the explanatory variables. This shows the spatial correlation existing between the variables and the dependent variable. It should be noted that the greatest flexibility changes in health status were characterized by spatially lagged dependent variable.

Table 2. Results of models comparison tests

	OLS	SAR	SEM	SDM (lag)	SDM (error)
Global Moran's I for regression residuals	0.395 (< 0.001)	-	-	-	-
Lagrange Multiplier Test (LM)	-	163.394 (<0.001)	132.680 (< 0.001)	-	-
Robust Lagrange Multiplier Test (RLM)		31.203 (<0.001)	0.489 (0.484)	-	-
Log likehood	-32.386	43.207	40.571	59.475	59.231
AIC	82.772	-66.415	-61.141	-84.950	-84.462
Likelihood Ratio test (LR)	-	151.19 (<0.001)	-145.913 (<0.001)	-183.722 (<0.001)	-183.233 (<0.001)

Source: Own calculations on the basis of Central Statistical Office in R Cran 3.1.0.

Table 3. Results of models estimation

	OLS	SAR	SEM	SDM (lag)	SDM (error)
(Intercept)	-0.187 (0.741)	-0.549 (0.211)	2.125 (<0.001)	**-2.237 (<0.001)**	**-3.460 (0.002)**
ln_DENSITY	**0.060 (0.003)**	**0.038 (0.015)**	**0.043 (0.023)**	0.029 (0.138)	0.023 (0.215)
ln_PH	**0.278 (<0.001)**	**0.103 (0.026)**	0.081 (0.091)	**0.139 (0.005)**	**0.179 (<0.001)**
ln_WATER	**0.301 (<0.001)**	**0.175 (<0.001)**	**0.197 (<0.001)**	**0.197 (<0.001)**	**0.208 (<0.001)**
ln_FOREST	**0.047 (0.038)**	0.014 (0.411)	0.022 (0.273)	0.019 (0.324)	0.025 (0.205)
ln_CO2	**-0.016 (0.019)**	-0.004 (0.453)	-0.004 (0.423)	-0.003 (0.598)	-0.003 (0.607)
ln_UEMP	**-0.152 (<0.001)**	**-0.061 (0.042)**	-0.047 (0.204)	-0.069 (0.064)	**-0.089 (0.014)**
ln_SPORT	**0.214 (<0.001)**	**0.123 (<0.001)**	0.057 (0.094)	**0.068 (0.049)**	**0.113 (0.002)**
lag ln_HI **(***rho coeff.***)**	-	**0.637 (<0.001)**	-	**0.601 (<0.001)**	-
lag error **(***lambda coeff.***)**	-	-	**0.709 (<0.001)**	-	**0.626 (<0.001)**

	OLS	SAR	SEM	SDM (lag)	SDM (error)
lag ln_DENSITY	-	-	-	0.014 (0.653)	0.079 (0.059)
lag ln_PH	-	-	-	**0.194 (0.009)**	**0.408 (<0.001)**
lag ln_WATER	-	-	-	**-0.114 (0.042)**	0.038 (0.601)
lag ln_FOREST	-	-	-	0.021 (0.609)	0.057 (0.248)
lag ln_CO2	-	-	-	-0.004 (0.635)	-0.008 (0.508)
lag ln_UEMP	-	-	-	-0.056 (0.301)	-0.103 (0.117)
lag ln_SPORT	-	-	-	**0.174 (0.005)**	**0.327 (<0.001)**

Source: Own calculations on the basis of Central Statistical Office in R Cran 3.1.0

5. Conclusions

The main aim of this paper is to verify which determinants of health influence the public health while analyzing neighbouring regions.

It should be noted that the proposed set of variables does not cover a wide range of variables which characterize the state of health of the population. Verification of the relationship between the level of health was determined by the index value of health and determinants having impact on health, the environment indicates the importance of the environment of life. The environment is understood not only as natural resources, but also basic technical and services infrastructure as well as living conditions.

A positive impact on health, according to the estimates of the spatial Durbin model, was observed in case of the location of pharmacies, the proportion of people using the wastewater treatment plant and the number of people exercising at sports clubs per 1000 inhabitants in the studied regions. Taking into account the impact of the global spatial interaction, it should be indicated that the positive impact on the general state of the health of neighbors, was exerted by the location of pharmacies in neighboring counties and the number of people exercising in sports clubs. Referring to the dependency of the general level of health and the number of trainees it could be concluded that the regions show the similarity in terms of patterns of health promotion. A negative impact on the level of health of the population was noted in case of people benefiting from the treatment plant. This relationship may be connected with high diversity of districts in terms of equipment in the sewage system and the pressures on the environment.

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Streszczenie

DETERMINANTY PRZESTRZENNEGO ZRÓŻNICOWANIA STANU ZDROWIA LUDNOŚCI

Stan zdrowia ludności jest jednym z podstawowych czynników rozwoju społecznego. Wyniki badań empirycznych, wskazują na szereg czynników warunkujących poziom zdrowia ludności, związanych m.in. z dostępem do usług opieki zdrowotnej, poziomem zanieczyszczeń środowiska, zamożnością społeczeństwa. Należy przypuszczać, że obserwowane dysproporcje w poziomie stanu zdrowia stanowią odwzorowanie rozkładów poszczególnych determinant. Celem artykułu jest ocena istotności głównych czynników wpływających na występowanie przestrzennych dysproporcji w poziomie rozwoju społecznego powiatów NTS-4, pod względem stanu zdrowia ludności. Analiza zależności została przeprowadzona na podstawie oszacowań przestrzennego modelu Durbina (ang. Spatial Durbin Model, SDM), uwzględniającego wpływ sąsiedztwa jednostek przestrzennych na poziom wartości zmiennej objaśnianej, jak i zmiennych objaśniających. Wielkością aproksymującą poziom rozwoju społecznego pod względem stanu zdrowia ludności w badaniu jest wartość indeksu agregatowego, stanowiącego składową lokalnego wskaźnika rozwoju społecznego LHDI (ang. Local Human Development Index).

***Słowa kluczowe**: model przestrzenny Durbina, stan zdrowia ludności, lokalny wskaźnik rozwoju społecznego*