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ELŻBIETA ANTCZAK*

Economic Development And Transfrontier Shipments Of Waste In Poland – Spatio-Temporal Analysis

Abstract

The aim of the paper is to apply the spatio-temporal Environmental Kuznets Curve (SpEKC) to test the relationship between economic growth and the amount of collected mixed municipal waste. The analysis was conducted at the level of sixty-six Polish sub-regions. The study contained selected environmental indicators. The dependent variable - the amount of municipal waste generated in kilograms per capita characterized the state of the environment. The GDP per capita in constant prices (as an explanatory variable) presented the level of economic development of the sub-regions. In the empirical part of the research there were used spatial panel data models based on EKCs. It determined the levels of economic development, at which the amount of produced wastes has fallen or increased, depending on the wealth of the region. The application of different types of spatial weight matrices was an important element of this modelling. Data obtained the years 2005-2012. Models were estimated in the RCran package.

Keywords: *spatial panel data models, Environmental Kuznets Curve, sustainable development, waste management, spatial weight matrices*

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1. Introduction

At the time of global ecological threats more and more attention is paid to issues connected with sorting and recycling of waste. The theory of sustainable development assumes minimizing the impact of economic growth on the quantity of produced waste.[1] Economic globalization, enhancement of the material quality of life, increasing production of consumer goods and ever faster technological progress result in shorter and shorter "lives" of commonly used goods, hence contributing to the excessive production of waste (Holger 2010, pp. 501-511). Therefore, the implementation of the principles of sustainable development into local and global regional[2] policies has become not only a duty (arising from European and international laws)[3] but also a necessity. At present, along with the problem of global air degradation, the production and interregional shipments of waste have become a serious threat as well (EEA 2012, p. 5). Unlike the protection of the atmosphere against pollution, progress in rationalizing waste management has been very slow.[4] There is still no effective mechanism created for the sorting, recycling and shipment of waste.[5] As a result, most of the waste ends up in landfills or is exported to countries technologically prepared to recycle it. In Poland, there is only one municipal waste incineration plant (Targówek-Warsaw) and six others are under construction[6], while there are as many as over 400 such facilities in Europe alone.[7] The transboundary shipment/movement of waste means its export, import, transit[8] and spatial interactions (autocorrelation) occurring in its volumes. In the case of the discussed phenomenon, spatial autocorrelation is a situation where the quantity

[1] Midterm aims of waste management till 2016th, see: Council of Ministers, *The National Environmental Policy for 2009-2012 and its 2016*, Warsaw 2008.

[2] In the paper the region means an administrative unit localised in the geographical area. Economic develomept means the quantitative and qualitative changes in the economy which drive to rise of GDP, standard of living and environmental sustaintibility.

[3] Council of European Union, *Review of the EU Sustainable Development Strategy (EU SDS) −Renewed Strategy*, Brussels 2006.

[4] Polish national Parliament, The Act of 13 September 1996 *on maintaining tidiness and order within communes*, Warsaw 1996.

[5] Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste, in Poland the a*ct of* 29 June 2007 on the *international shipments* of *waste.*

[6] http://budownictwo.wnp.pl/spalarnie-odpadow-co-zrobilismy-co-robimy-co-przed-nami, 220 908_1_0_0.html, date: 28.04.2014.

[7] http://spalarnie-odpadow.pl/spalarnie-w-polsce-i-na-swiecie/, date: 28.04.2014.

[8] Basel Convention from date: 22.03.1989., Polish status of ratification: 10.01.1992., Chief Inspector of Environmental Protection, Transgraniczne przemieszczanie odpadów - nadzór i kontrola Inspekcji Ochrony Środowiska, Aura 9/2012, pp. 19-22.

of waste collected in a region affects the level of that phenomenon in adjacent regions. The monitoring of the changing volume of generated waste dependent on a region's wealth is among the principles of sustainable development. On the other hand, the quantification and identification of economic, ecological and spatial relationships is possible through, among others, the use of appropriate measurement methods, e.g. spatial panel data models based on the Environmental Kuznets Curve (EKC). The aim of the paper is to verify the hypothesis of the Spatio-temporal Environmental Kuznets Curve (SpEKC), where the curve describes the relation between socio-economic growth and the quantity of collected municipal waste in kilograms per capita at the level of Poland's subregions. The empirical part uses spatial panel models based on EKC functions. That serves to determine economic development levels of specific units for which the quantity of waste decreased or increased depending on a subregion's development. An important element of models was the application of various types of spatial weights matrices. Data concerned the years 2005-2012. In order to meet the objective of the study, research questions that have been put forward concern: 1) the scale and algorithm of the impact of economic development on the quantity of collected waste; 2) the possibility to determine economic development levels of specific subregions for which the quantity of produced waste fell or rose depending on a subregion's wealth; and 3) the impact of different types of spatial weights matrices used on the values of received results.

2. Research methodology and characteristics of variables

The main assumption of the conducted analysis is to verify the relationship between the volume of municipal waste (reflecting the environmental pollution level) and the economic development of a subregion, taking into account interregional interactions. One of the methods of modelling economic and ecological relationships, considering the specificity of a region and spatial autocorrelation, are spatial panel data models based on the functions of the Environmental Kuznets Curve (EKC).[9] The EKC is a curve (its basic version is a second degree polynomial – the inverted "U" letter)[10] expressing a change in the volume of environmental pollution depending on an increase in economic development (1):

[9] More details of different EKCs, in: (Antczak, 2012, pp. 113-130).

[10] More about EKC assumptions in: (Stern, 2004, pp. 1419–1439).

$$lE_{it} = -\alpha_i + \alpha_1 lED_{it} - \alpha_2 (lED_{it})^2 + \mathbf{x}_{it}^T \boldsymbol{\beta} + u_{it} \quad (1)$$

where: Eit-environmental degradation indicator, EDit- measurement of economic development, $\mathbf{x}_{it}^T$ - matrix/vector of explanatory variables,αi-fixed effects, uit–error term;

Theoretical premises of the curve support transforming variables into logarithms.[11] The idea of the classic EKC (formula 1) bases on seeking an inflection point or – for cubic functions – inflection points (extremum/a of a function). The inflection point of the basic EKC version is such a level of economic development past which a potential drop in environmental pollution begins.

In this analysis, the quantity of gathered moxed municipal waste was made dependent on the economic development level, population density, investments on waste management and number of emigrants. Table 1 contains values of characteristics and coefficients of correlation indicating the scale and direction of interactions among variables.

Table 1. Values of characteristics and correlation coefficients

	units	MU_{it}	lMU_{it}	average	min	max	CV in %
MU_{it}	kg/capita	1	-	162,5	55,5	360,4	31
lMU_{it}	-	-	1	5,1	4,0	5,9	6
GDP_{it}	PLN thousand/capita	0,59	-	30,4	14,6	124,8	46
$lGDP_{it}$	-	-	0,59	3,3	2,9	4,8	11
INV_{it}	PLN/capita	-0,64	-	21	0,1	273,9	151
$lINV_{it}$	-	-	-0,69	2,3	-3,3	5,6	55
PD_{it}	persons/square km	0,59	-	388	44	3318	192
lPD_{it}	-	-	0,62	5,1	3,8	8,1	22
PFE_{it}	%	-0,49		5,7	0,1	33,7	90
$lPFE_{it}$	-	-	-0,59	1,4	-3	3,5	63

MUit -amount of collected municipal waste during the year GDPit - gross domestic product in constant price, INVit - amount of expenditure on waste management, PDit - population density, PFEit - share of foreign emigration in the total number of emigrants; l -logarithm. Some of variables are characterised by asymmetry. However, it implies the heterogenity which in this case is a desirable property.
Tests results: Levin-Lin-Chu the presence of unit root for the panel indicated that all variables are stationary also with time trend, (the analysis was conducted in Stata 11).

Source: own elaboration.

[11] More in: (Antczak, 2012, pp. 65-66).

Data presented in Table 1 allow to observe the following relationship: the higher the economic development level and population density, the bigger the quantity of collected waste. The opposite situation occurs for variables concerning the value of outlays on waste management and the share of the number of emigrants going abroad in the total volume of emigration. Results of this part of analysis indicate that it is possible to use the presented quantitative methods (describing economic, social and ecological relationships). However, the cause and effect relationships among the described variables are also affected by other factors, not given in Table 1, e.g. spatial interactions. Thus, the next step in the study was to formally verify interregional relationships by using appropriately selected tools of exploratory spatial data analysis (compare: Table 2) and spatial econometrics (compare: Tables 3-4).

Table 2 presents results of the analysis which served to verify whether spatial autocorrelation occurred for the quantity of municipal waste in Poland.

Table 2. Values of global Moran's I statistics for dependent variable MUit

	Moran *I*	***p*-value**
	Variable: MU (*lMU*)	
2005	0,40	<0,01
	0,41	*<0,01*
2006	0,38	<0,01
	0,39	*<0,01*
2007	0,38	<0,01
	0,39	*<0,01*
2008	0,40	<0,01
	0,41	*<0,01*
2009	0,49	<0,01
	0,50	*<0,01*
2010	0,47	<0,01
	0,51	*<0,01*
2011	0,54	<0,01
	0,56	*<0,01*
2012	0,55	<0,01
	0,57	*<0,01*

Note: the accepted level of statistical significance: $\alpha = 0,05$. Italic: variable transformed into the logarithms. The statistical significance verification is based on randomization tests, more e.g. in: (Suchecki, 2010, p. 120).

Source: own elaboration.

In all the years of the analysed period the quantity of waste collected in Poland's subregions was characterized by statistically significant positive spatial autocorrelation, which, in space, means the grouping together of subregions with similar quantities of municipal waste adjacent to one another (subregions producing large quantities of waste are adjacent to subregions with high values of that variable; similarly: units producing less waste are situated adjacent to regions with low levels of the phenomenon). Moreover, data contained in Table 2 indicate that the strength of statistically significant spatial relationships increased in the years 2005-2012 (an average rise of 38% in Moran's I statistic value in 2012 as compared to 2005). Thus, the production of waste in a subregion significantly affected the volume of that phenomenon in its adjacent subregions (according to the assumed spatial weights matrix).

In order to simultaneously take into account the above ecological and economic relationships (Table 1) and processes of the transboundary shipment of waste (Table 2), spatial panel data models with fixed effects based on the EKC function (FEM-EKC) and containing a spatially lagged dependent variable (SAR-FEM-EKC[12]) were used. Eventually, it appeared, however, that the most appropriate form of the EKC would be the inverted Kuznets cubic curve (2):

$$\begin{aligned} lMU_{it} &= \alpha_i - \alpha_1 lGDP_{it} + \alpha_2 (lGDP_{it})^2 - \alpha_3 (lGDP)^3 - \alpha_4 lINV_{it} + \\ &+ \alpha_5 lPD_{it} - \alpha_6 lPFE_{it} + \rho l\mathbf{W}MU_{it} + u_{it} \end{aligned} \qquad (2)$$

The curve described by formula 2 expresses a relationship between an increase in economic development and the quantity of collected municipal waste per capita. Thus, there are three phases of the course of those phenomena over time (received signs of structural parameters at the lGDPit variable). Namely, in the first stage of modelling, a rise in GDP per capita results in a drop in the quantity of generated waste. In the second phase, past an inflection point, an increase in economic development leads to a rise in the volume of waste. In turn, in the third and last stage of the course of the phenomenon over time, the second inflection point appears (the second extremum of the function, a particular value of GDP per capita), past which a decrease in the quantity of municipal waste occurs. [13]

The use of a cross-sectional sample in the form of spatially located data requires taking into account spatial interactions. In SAR-FEM models, where spatial relationships concern the dependent variable (here: MUit), spatial autoregression occurs, i.e. the value of the dependent variable for other localities (areas, regions, geographical points) affect values of that variable in a given

[12] *Spatial AutoRegressive* panel data Models with *Fixed Effects based on EKC function.*

[13] Foreign literature: (Ichinose, et al., 2011).

i locality (WMUit). In spatial econometrics models, a difficult and important issue is to include spatial autocorrelation in the form of an appropriately chosen spatial weights matrix. The building and application of a particular type of the matrix should depend on the objective and assumptions of the conducted analysis, specificity of a phenomenon and used quantitative method. What is more, received research results may differ significantly depending on the assumed spatial weights matrix type as well. [14]

3. Spatial weights matrices - selection

The presence of statistically significant interregional relationships (concerning transboundary shipment of waste, compare: section 2 of the article) was a premise for considering an interaction element in econometric modelling. The applied FE panel models allow to estimate individual effects (specific to a region in this case). In turn, the selection of the SAR model assumes the introduction of a spatially lagged dependent variable (lWMUit) into the set of independent variables so that the variable retains the properties of a dependent variable. The spatial weights matrix should reflect the nature and specificity of interregional interactions (adjacency of a region affects the volume of produced waste in other units situated in that geographical space; compare: Table 1). In order to reflect the described spatial relationships, three spatial weights matrices were built: W1, W2, W3.

W1 – a matrix where values of weights were determined based on a spatial trend. The dependent variable in the estimated surface trend model was the quantity of municipal waste collected in subregions (MUit). The form of the model was described by formula (3):

$$MU_{it} = \beta_0 X_{coor}^{\beta_1} Y_{coor}^{\beta_2} e^{\varepsilon_{it}} \tag{3}$$

where: Xcoor, Ycoor-coordinates of centers of regions, ε_{it} -error term, β0, β1, β2-structural coefficients of the model;

Upon estimating parameter values, the model described by formula (3) took the form of (4):

[14] More about spatial weights matrixes in: (Suchecki, 2010).

$$\hat{MU}_{it} = 4{,}8 X_{coor}^{-1{,}4} Y_{coor}^{0{,}8} \tag{4}$$

t	(51,5)	(-5,4)	(0,9)
$S(b_j)$	(0,1)	(0,3)	(0,9)

where: t-values of t-Student's statistics, S(bj)-average standard of coefficients errors;

Evaluations of the estimated parameters (β0, β1) of model (4) proved to be statistically significant at the assumed significance level of α=0,05 (for the critical value of t*=1,7).[15] That significance confirms the presence of a surface trend in Poland's subregions in respect of the quantity of collected municipal waste. What is more, the global spatial trend in the volume of the phenomenon was upward in the years 2005-2012 (β0=4,8). The sign of the parameter estimation at the X coordinate is negative (-1,4). That indicates a downward spatial trend from the West towards the East of Poland, i.e. Western subregions were characterized by a higher level of the analysed variable than Eastern subregions. The received model estimation results (4) revealed the absence of a statistically significant spatial trend in the quantity of collected municipal waste from the South towards the North. Based on information obtained about spatial trends in the average level of waste collected in Poland in the years 2005-2012, a spatial weights matrix was built. The matrix took into consideration the spatial trend through assigning higher weights to subregions in the West of Poland (reflecting the spatial trend) and lower – to subregions in the East.

W2 – a weights matrix built on the basis of the first order adjacency for the eight closest neighbours.[16] In some cases waste is shipped over a close distance (just across the boundary of a given subregion). Thus, the idea behind the weights matrix structure was to take the direct adjacency of a given area (subregion) into consideration.

W3 – a weights matrix built based on distances from the determined geographical centres of specific subregions. In the case of transboundary shipments of waste, waste is transported over short distances (below 50 km) but also over distances above a thousand kilometres. The largest recipients of municipal waste (suitable for recycling) include the Northern subregions of Poland, which further export the gathered waste to Scandinavian countries, and Western subregions, exporting the "raw material" further to Western Europe (to

[15] The chosen model was the exponential trend surface model because it was the most effective (test on normality of errors: Jarque-Bera=1,8 with p-value=0,4, diagnostics for heteroskedasticity: Breusch-Pagan=2,4 with p-value=0,3), lower Akaike and Schwarz info criterion than linear, models as a polynomial of the second and the third degree.

[16] The eight nearest neighbours because in Poland there is no region with more than eight adjoining regions. More about spatial weights matrices, see in: (Suchecki, 2010, pp. 28-33).

Germany or Switzerland). The main recipients of sorted municipal waste in Europe are: Switzerland, Germany, Austria, Portugal and Scandinavian countries. In those countries, highly developed state-of-the-art technologies intensify waste recycling processes (over 30% of locally generated waste is recycled)[17]. In the years 2005-2012 municipal waste was most commonly shipped within Poland to the following subregions: Włocławski, Grudziądzki, Wrocławski, Suwalski, Łomżyński and Ostrołęcko-Siedlecki.[18] Therefore, the constructed spatial weights matrix considered regions located at different geographical distances from one another. The lengths of the radii of circles (within which specific subregions, as potential recipients of waste, were located) were from 132 km to 648 km (the stretch of Poland). Weight values were assigned depending on geographical distances from the centre of a specific region.

The subsequent part of the article presents estimation results of spatial panel models based on the functions of the Environmental Kuznets Curve using the three different spatial weights matrices (**W₁**, **W₂**, **W₃**).

4. Results

The aim of the performed econometric analysis was to verify the hypothesis of the spatiotemporal environmental Kuznets curve in respect of the volume of waste in Poland's subregions in the years 2005-2012, depending on the economic development level of selected regions. An important element of the analysis was the application of various types of spatial weights matrices. Results of the estimations of classic and spatial EKC models with spatial weights matrices W1, W2 and W3 are shown in Tables 3 and 4.

Table 3. Results of SAR-FEM-EKCs estimation, n=528

SAR1-FEM-EKC $lMU_{it} = \alpha_i - \alpha_1 lGDP_{it} + \alpha_2 (lGDP_{it})^2 + \alpha_3 (lGDP_{it})^3 - \alpha_4 lINV_{it} + \alpha_5 lPD_{it} - + \alpha_6 lPFE +_{it} \rho_1 l\mathbf{W_1} MU_{it} + u_{it}$

parameter	value	t-student	std.error	p-value
const	11,62	5,33	2,18	<0,01
α1	-7,97	-4,64	1,72	<0,01
α2	2,31	4,75	0,49	<0,01
α3	0,22	-4,91	0,05	<0,01
α4	-0,0004	-0,12	0,003	0,90
α5	0,24	2,74	0,14	0,01
α6	-0,02	2,75	0,005	0,01
ρ1	0,26	4,80	0,06	<0,01

[17] www.epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home, date: 20.04.2014.

[18] www.stat.gov.pl - Bank Danych Lokalnych, date: 28.04.2014.

<table>
<tr><td colspan="5">pseudo R2=0,96; Chow's test on fixed effects significance F*(456, 65)=1,34, F=1,78, F>F*; normality of residuals: Shapiro-Wilk, W = 0,98, p-value = 0,14, stationary of residuals: Levin-Lin-Chu, without time trend H1 for -28,1 (0,000), with time trend H1 for -20,8 (0,000); t*=1,89, HQC=-2631</td></tr>
<tr><td colspan="5">Chow's test on spatial fixed effects: FSAR-FEM>F*; 3,92>2,94, SAR1-FEM–EKC better than FEM-EKC;</td></tr>
<tr><td colspan="5">SAR2-FEM-EKC $lMU_{it} = \alpha_i - \alpha_1 lGDP_{it} + \alpha_2 (lGDP_{it})^2 + \alpha_3 (lGDP_{it})^3 - \alpha_4 lINV_{it} + \alpha_5 lPD_{it} - + \alpha_6 lPFE +_{it} \rho_2 l\mathbf{W}_2 MU_{it} + u_{it}$</td></tr>
<tr><td>parameter</td><td>value</td><td>t-Student</td><td>std.error</td><td>p-value</td></tr>
<tr><td>const</td><td>10,3</td><td>4,75</td><td>2,17</td><td><0,01</td></tr>
<tr><td>α1</td><td>-7,63</td><td>-4,46</td><td>1,71</td><td><0,01</td></tr>
<tr><td>α2</td><td>2,21</td><td>4,56</td><td>0,49</td><td><0,01</td></tr>
<tr><td>α3</td><td>-0,21</td><td>-4,71</td><td>0,05</td><td><0,01</td></tr>
<tr><td>α4</td><td>-0,001</td><td>-0,31</td><td>0,004</td><td>0,75</td></tr>
<tr><td>α5</td><td>0,30</td><td>2,19</td><td>0,14</td><td>0,03</td></tr>
<tr><td>α6</td><td>-0,02</td><td>-2,43</td><td>0,01</td><td>0,02</td></tr>
<tr><td>ρ2</td><td>0,34</td><td>5,58</td><td>0,07</td><td><0,01</td></tr>
<tr><td colspan="5">pseudo R2=0,95; Chow's test on fixed effects significance F*(456, 65)=1,34, F=1,88, F>F*; normality of residuals: Shapiro-Wilk, W = 0,98, p-value = 0,11, stationary of residuals: Levin-Lin-Chu, without time trend H1 for -27,5 (0,000), with time trend H1 for -20,1 (0,000); t*=1,89, HQC=-2609</td></tr>
<tr><td colspan="5">Chow's test on spatial fixed effects: FSAR-FEM>F*; 4,44>2,94, SAR2-FEM–EKC better than FEM-EKC;</td></tr>
<tr><td colspan="5">SAR3-FEM-EKC $lMU_{it} = \alpha_i - \alpha_1 lGDP_{it} + \alpha_2 (lGDP_{it})^2 + \alpha_3 (lGDP_{it})^3 - \alpha_4 lINV_{it} + \alpha_5 lPD_{it} - + \alpha_6 lPFE +_{it} \rho_3 l\mathbf{W}_3 MU_{it} + u_{it}$</td></tr>
<tr><td>parametr</td><td>value</td><td>t-Student</td><td>stnd. error</td><td>p-value</td></tr>
<tr><td>const</td><td>9,87</td><td>7,85</td><td>1,26</td><td>0,000</td></tr>
<tr><td>α1</td><td>-8,43</td><td>-4,80</td><td>1,75</td><td><0,01</td></tr>
<tr><td>α2</td><td>2,42</td><td>4,87</td><td>0,49</td><td><0,01</td></tr>
<tr><td>α3</td><td>-0,23</td><td>-4,97</td><td>0,05</td><td><0,01</td></tr>
<tr><td>α4</td><td>-0,001</td><td>-0,27</td><td>0,003</td><td>0,79</td></tr>
<tr><td>α5</td><td>0,32</td><td>2,24</td><td>0,14</td><td>0,03</td></tr>
<tr><td>α6</td><td>-0,02</td><td>-2,34</td><td>0,01</td><td>0,02</td></tr>
<tr><td>ρ3</td><td>0,43</td><td>3,23</td><td>0,13</td><td>0,001</td></tr>
<tr><td colspan="5">pseudo R2=0,95; Chow's test on fixed effects significance F*(456, 65)=1,34, F=1,31, F<F*; normality of residuals: Shapiro-Wilk, W = 0,96, p-value = 0,09, stationary of residuals: Levin-Lin-Chu, without time trend H1 for -25,2 (0,000), with time trend H1 for -19,4 (0,000); t*=1,89, HQC=-2583</td></tr>
<tr><td colspan="5">Chow's test on spatial fixed effects: FSAR-FEM<F*; 1,20<2,94, SAR3-FEM–EKC not better than FEM-EKC;</td></tr>
</table>

Spatial models are estimated by ML; characteristics of matrices see the 3rd part of the paper significance level: α=0,05, H1: Panels are stationary;

Source: own elaboration in RCran.

Evaluations of parameters at the spatially delayed variable in all the three models proved to be statistically significant, which means that a rise in the volume of generated waste was affected by the economic development and mutual adjacency of the regions. The strength of the impact depended on the type of the introduced spatial weights matrix (ρ1=0,26, ρ2=0,34, ρ3=0,43). Therefore, considering spatial interactions in the form of the W matrix proved to be justified. Furthermore, all the models confirmed the occurrence of two inflection points (GDP levels past which a rise and drop in the quantity of collected waste would respectively take place). However, not all the spatial models turned out to be qualitatively better than the zero and non-spatial models. Based on the values of Chow test statistics, a SAR3-FEM-EKC was rejected, for which the introduction of fixed and spatial effects appeared to be unjustified. In turn, as for the other two models: SAR1-FEM-EKC and SAR2-FEM-EKC, the model with weights matrix W1, built on the basis of the spatial trend in the quantity of municipal waste collected in subregions per year, was selected for the final analysis (among others: lower value of HQC, higher level of statistical significance of parameter evaluations, higher coefficient of determination). Then, the results were analysed in detail and compared with non-spatial modelling results (Table 4).

Table 4. Results of estimation of FEM-EKC and SAR1-FEM-EKC

FEM-EKC	$lMU_{it} = \alpha_i - \alpha_1 lGDP_{it} + \alpha_2 (lGDP_{it})^2 + \alpha_3 (lGDP_{it})^3 - + \alpha_4 lINV_{it} + \alpha_5 lPD_{it} - \alpha_6 lPFE + u_{it}$			
parameter	value	t-student	std.error	p-value
const	13,02	5,39	2,42	<0,01
α1	-8,11	-4,26	1,90	<0,01
α2	2,33	4,31	0,54	<0,01
α3	-0,22	-4,41	0,05	<0,01
α4	-0,001	-0,21	0,003	0,83
α5	0,28	1,82	0,15	0,07
α6	-0,03	-3,19	0,01	0,02
αi	tr=13,29, sł=12,67, gd=13,15, el=13,13, ko=13,46, su=13,12, sa=13,38, eł=13,32, sz=13,55, ol=13,33, so=13,20, Szcz=12,98, gr=13,13, pi=13,33, ło=13,08, bt=13,17, bi=13,36, go=13,57, wł=13,07, po=13,22, ci=13,12, P=12,86, kń=13,20, W=13,05, wz=13,21, os=12,91, ww=12,97, sk=13,39, z=13,13, le=12,75, ba=12,97, ka=12,55, Ł=12,78, si=13,21, łó=13,02, ra=13,02, pi=12,66, pu=13,05, lu=13,15, wr=13,57, lg=12,79, Wr=13,44, je=12,80, ki=12,92, cz=12,63, op=13,28, sj=12,57, wa=13,38, ta=12,67, by=13,1, gl=13,00, ny=13,16, so=13,03, ka=12,81, kr=12,45, ry=12,86, ty=12,88, K=12,94, rz=12,55, ta=12,56, oś=12,46, be=12,73, pr=12,69, kś=12,84, no=12,87, no=12,6;			

pseudo R2=0,92; Chow's test on fixed effects significance F*(456, 65)=1,34, F=1,58, F>F*; normality of residuals: Shapiro-Wilk, W = 0,98, p-value = 0,09, stationary of residuals: Levin-Lin-Chu, without time trend H1 for -23,4 (0,000), with time trend H1 for -17,6 (0,000); t*=1,89, HQC=-837				
Turning points: 23,3 and 44,7 PLN per capita				
SAR1-FEM-EKC $lMU_{it} = \alpha_i - \alpha_1 lGDP_{it} + \alpha_2 (lGDP_{it})^2 + \alpha_3 (lGDP_{it})^3 - \alpha_4 lINV_{it} + \alpha_5 lPD_{it} - + \alpha_6 lPFE +_{it} \rho_1 l\mathbf{W_1} MU_{it} + u_{it}$				
parameter	value	t-student	std.error	p-value
const	11,62	5,33	2,2	<0,01
α1	-7,97	-4,64	1,72	<0,01
α2	2,31	4,75	0,49	<0,01
α3	0,22	-4,91	0,05	<0,01
α4	-0,0004	-0,12	0,003	0,90
α5	0,24	2,74	0,14	0,01
α6	-0,02	2,75	0,005	0,01
ρ1	0,26	4,80	0,06	<0,01
αi	tr=11,82, sł=11,34, gd=11,70, el=11,69, ko=11,97, su=11,67, sa=11,93, eł=11,90, sz=12,02 ol=11,92, so=11,69, Szcz=11,59, gr=11,68, pi=11,86, ło=11,67, bt=11,78, bi=11,99, go=12,09, wł=11,63, po=11,79, ci=11,68, P=11,53, kń=11,79, W=11,75, wz=11,83, os=11,50, ww=11,57, sk=11,56, z=11,91, le=11,65, ba=11,39, ka=11,55, Ł=11,28, si=11,33, łó=11,87, ra=11,63, pi=11,62, pu=11,32, lu=11,78, wr=11,66, lg=12,12, Wr=11,48, je=11,97, ki=11,45, cz=11,51, chz=11,27, op=11,85, sj=11,18, wa=11,93, ta=11,37, by=11,65, gl=11,57, ny=11,73, so=11,65, ka=11,42, kr=11,09, ry=11,47, ty=11,51, K=11,38, rz=11,22, ta=11,18, oś=11,35, be=11,28, pr=11,52, kś=11,54, no=11,29;			
pseudo R2=0,96; Chow's test on fixed effects significance F*(456, 65)=1,34, F=1,78, F>F*; normality of residuals: Shapiro-Wilk, W = 0,98, p-value = 0,14, stationary of residuals: Levin-Lin-Chu, without time trend H1 for -28,1 (0,000), with time trend H1 for -20,8 (0,000); t*=1,89, HQC=-2631				
Chow's test on spatial fixed effects: FSAR-FEM>F*; 3,92>2,94, SAR1-FEM–EKC better than FEM-EKC;				
turning points: 17,3 and63,4 PLN per capita				

tr-trójmiejski, sł-słupski, gd-gdański, el-elbląski, ko-koszaliński, su-suwalski, sa-stargardzki, eł-ełcki, sz-szczeciński, ol-olsztyński, so-starogardzki, Szcz- Szczecin, gr-gudziądzki, pi-pilski, ło-łomżyński, bt-bydgosko-toruński, bi-białostocki, go-gorzowski, wł-włocławski, po-poznański, ci-ciechanowski, P-Poznań, kń-koniński, W-Warszawa, wz-warszawski-zachodni, os-ostrołęcko-siedlecki, ww-warszawski-wschodni, sk-skierniewicki, z-zielonogórski, le-leszczyński, ba-bialski, ka-kaliski, Ł-Łódź, si-sieradzki, łó-łódzki, ra-radomski, pi-piotrkowski, pu-puławski, lu-lubelski, wr-wrocławski, lg-legnicko-głogowski, Wr-Wrocław, je-jeleniogórski, ki-kielecki, cz-częstochowski, chz-chełmsko-zamojski, op-opolski, sj-sandomiersko-jędrzejowski, wa-wałbrzyski, ta-tarnobrzeski, by-bytomski, gl-gliwicki, ny-nyski, so-sosnowiecki, ka-katowicki, kr-krakowski, ry-rybnicki, ty-tyski, K-Kraków, rz-rzeszowski, ta-tarnowski, oś-oświęcimski, be-bielski, pr-przemyski, kś-krośnieński, no-nowosądecki;

Spatial models were estimated by ML, non-spatial model by OLS; significance level: α=0,05.

Source: own elaboration in RCran.

Results contained in Table 4 reveal that both the non-spatial model (FEM-EKC) and the spatial model (SAR1-FEM-EKC) indicate that the third degree function (polynomial) was properly selected as the most appropriate form for the analysis of relationships between economic development and "production" of municipal waste in Poland (statistical significance of evaluations of estimated structural parameters at the GDPit variables). The first extremum of the model without interregional relationships (without the W matrix) indicated the economic development level (PLN 23,2 per capita), which was attained by 19 subregions before or in 2005 (which accounted for as few as 29% of the analysed units) and exceeded by as many as 92% of nuts3 in 2012. Hence, after a subregion achieved the GDP described by the first inflection point, the further process of GDP increase led to a rise in waste quantity. As for the models with spatial interactions, the first inflection point was at the level of PLN 17,3 per capita. Collected data suggest that before 2005 (or exactly at that point in time) as many as 50 subregions attained that development level, which accounted for 76% of all the analysed units. In 2012 all the subregions exceeded the first inflection point on the EKC curve, which clearly indicated the occurrence of the other inflection point in the course of the discussed economic and ecological relationship, which, in turn, is a property of inverted cubic EKC functions. According to the results of the non-spatial model estimations, the other inflection point was an unbelievably low level of economic development (PLN 44,7 per capita), past which further development generated the quantity of waste that did not pollute the environment. That would point to the effectiveness of actions carried out within the framework of waste management in Poland. Fourteen subregions attained such a GDP level (which accounted for 21% of all the units) in the years 2005-2012. Those were, among others, the city of Warsaw, Warszawski-Zachodni, Legnicko-Głogowski, Jeleniogórski, the city of Wrocław etc. On the other hand, results received in spatial modelling suggest an economic development level of PLN 63,4 per capita achievable by only four subregions in the analysed period: Warsaw, the city of Poznań, the city of Wrocław and the Legnicko-Głogowski subregion (where, despite the huge quantity of collected waste, its recycling reached 72%, with the national average at a little above 30%).[19] After exceeding that point, the above-mentioned subregions re-entered the path of sustainable development, regarding the natural environment as a luxury good (the effect of pro-ecological investments is the limiting and reduction of the annual quantity of collected waste).

The impact of the adjacency of regions on the quality of environment proved to be adverse (0.26·lW1MUit), which meant that a rise in the volume of

[19] SWD, Wojewódzki Plan Gospodarki Odpadami dla Województwa Dolnośląskiego 2012, Wrocław 2012.

waste in a subregion led to an average increase of 0,26% in the volume of that phenomenon in adjacent subregions (according to the assumed spatial weights matrix). [20] Moreover, interregional relationships caused the first inflection point to appear earlier than in the non-spatial model (PLN 17,3 per capita and PLN 23,3 per capita for the ordinary model respectively). That allows to infer that, at a lower level of economic development, every quantity of generated waste posed a threat to the environment. On the other hand, the other extremum of the function (past which a fall in the quantity of municipal waste occurred along with a rise in GDP per capita) "required" a higher level of subregions' development in spatial modelling than that indicated by the estimation results that did not take into account spatial relationships. That confirms the negative impact of adjacency on the level of the analysed phenomenon.

Estimation results of the spatial panel model with fixed effects revealed subregions which, to the largest and smallest extent, contributed to the total quantity of collected municipal waste (see Table 4), too. In the years 2005-2012 the smallest impact on environmental degradation by waste characterized the Krakowski and the biggest – the Legnicko-Głogowski subregions.

Other factors affecting the quantity of waste and considered in the study were population density, whose increase resulted in an average rise of 0,24% in the volume of collected waste, and the proportion of the number of emigrants going abroad in the total number of emigrants, whose rise caused the dependent variable to fall by an average of 0,02% (ceteris paribus). The value of outlays on waste management turned out not to exert a significant impact on the quantity of municipal waste collected over the year.

Eventually, the spatial model was of higher quality than the model without spatial interactions (higher values of statistics: R2 or the Chow test; lower values of the Hannan-Quinn Information Criterion).

5. Summary

Results of the conducted analysis indicate that there are relationships between the quantity of collected municipal waste and economic development of Poland's subregions - the third degree function of EKC (polynomial) was properly selected as the most appropriate form for the analysis of relationships between economic development and "production" of municipal waste in Poland (statistical significance of evaluations of estimated structural parameters at the

[20] Characteristics of weight matrices see part 3rd of the paper.

GDPit variables). Moreover, in most analysed Poland's subregions (94%), the processes of faster economic development threatened the quality of the environment, and thus the quality of life between years 2005-2012 (only 6% of the analysed regions exceeded the second inflection point past which the environment became a good worth investing in). As for the models with spatial interactions, the first inflection point was at the level of PLN 17,3 per capita. Collected data suggest that before 2005 (or exactly at that point in time) as many as 50 subregions attained that development level, which accounted for 76% of all the analysed units. The second turning point by the spatial modelling suggests the level of PLN 63,4 per capita of an economic development which was achievable only by four subregions in the analysed period: Warsaw, the city of Poznań, the city of Wrocław and the Legnicko-Głogowski subregion (where, despite the huge quantity of collected waste, its recycling reached 72%, with the national average at a little above 30%). After exceeding that point, the above-mentioned subregions re-entered the path of sustainable development, regarding the natural environment as a luxury good (the effect of pro-ecological investments is the limiting and reduction of the annual quantity of collected waste).

The results of the estimated EKC models confirmed that the level of the described phenomenon was also affected by interregional spatial interactions. The intensity and direction of transboundary shipments of waste were reflected by elements of the spatial weights matrix. The impact of the adjacency of regions on the quality of environment proved to be adverse (0.26·lW1MUit), which meant that a rise in the volume of waste in a subregion led to an average increase of 0,26% in the volume of that phenomenon in adjacent subregions. In turn, the occurring positive spatial autocorrelation resulted in an adverse impact of subregions' adjacency on the volume of waste. Furthermore, spatial panel models based on the Environmental Kuznets Curve reflected processes taking place on the specific planes of the analysed phenomenon more precisely than classic models.

The findigs are definitely relevant for policymaking. Since the results confirm that transboundary pollution associated with municipal waste is a major issue in Poland, one possible solution to reduce the amount of waste is to maximise recycling and re-use, to limit incineration to non-recyclable materials, to phase out landfilling to non-recyclable and non-recoverable waste, to ensure full implementation of the waste policy targets. However, the conducted study did not exhaust the issues raised in the article. They will be continued in further analyses aimed, among others, at the classification of subregions into groups (depending on the EKC function in a given region), replacement of the GDP variable with other variables and use of multi-equation spatial models. The analyses will still be focused on current issues such as: raising ecological awareness related to the rationalization of consumption and limiting of the quantity of generated pollution as well as the effective control of transboundary shipments of waste.

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Streszczenie

ROZWÓJ GOSPODARCZY A MIĘDZYREGIONALNE PRZEMIESZCZENIE ODPADÓW W POLSCE – ANALIZA PRZESTRZENNO-CZASOWA

Celem publikacji jest aplikacja przestrzenno-czasowej Środowiskowej Krzywej Kuznetsa (SpEKC, Spatiotemporal Environmental Kuznets Curve) do testowania zależności pomiędzy wzrostem gospodarczym a ilością zebranych zmieszanych odpadów komunalnych na poziomie podregionów Polski. Badanie przeprowadzono na podstawie wybranych wskaźników środowiskowych. Zmienna objaśniana, w postaci ilości zebranych odpadów komunalnych w kilogramach na mieszkańca, charakteryzowała stan środowiska naturalnego, a PKB na osobę w cenach stałych (jako zmienna objaśniająca) prezentowała poziom rozwoju gospodarczego poszczególnych podregionów Polski. W części empirycznej zastosowano przestrzenne modele panelowe oparte na funkcjach EKC. W ten sposób wyznaczono poziomy rozwoju gospodarczego poszczególnych jednostek, dla których ilość wytwarzanych odpadów spadała bądź wrastała w zależności od bogactwa podregionu. Ważnym elementem modeli była aplikacja różnych typów macierzy wag przestrzennych, które skonstruowano w oparciu o estymowane trendy przestrzenne dotyczące ilości produkowanych odpadów w Polsce oraz uwzględniając sąsiedztwo podregionów. Dane dotyczyły lat 2005–2012. Modele estymowano w pakiecie RCran.

Słowa klucze: *przestrzenne modele panelowe, Środowiskowa Krzywa Kuznetsa, zrównoważony rozwój, gospodarka odpadami, macierze wag przestrzennych*

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Selected Intangible Factors Of Regional Development: An Analysis Of Spatial Relationships

Abstract

As spatial diversity of economic development is one of the main problems of modern economies, researchers have attempted to define the conditions and factors influencing this phenomenon. Among others, two intangible factors are suggested: human capital and social capital (Herbst ed. 2007).

The primary objective of this work is a spatial and spatio-temporal analysis of the diversification of human and social capital within the Polish NUTS 3 subregions. The two detailed targets are constructing composite indicator of both of the mentioned types of capital as well as examining spatial interactions between human capital, social capital and the GNP level per capita.

The large diversification of human and social capital in the Polish subregions has been confirmed. Clusters of regions with low levels of human capital have been indicated, whereas in the case of social capital a grouping of its high values was observed. The research also confirmed the positive correlation between GNP per capita and human capital, with high values of both variables in the larget cities. Additionally, there are some subregions with high levels of economic development surrounded by low levels of human and social capital (Łódź, Szczecin, Wrocław). It is possible that high level of GNPpc in these regions was the incentive causing the relocation of human capital from the neighbouring regions. The correlation between GNPpc and social capital, where significant, is of the low-high type. These subregions are located in the east and south of Poland.

***Keywords**: human capital, social capital, regional development, exploratory spatial data analysis*

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1. Introduction

In classical economics, labour, land and capital were considered the main factors of production. Capital was understood as financial and material goods which may be disposed of if one has conducted profit-generating activities. However, effectively exploiting the available physical or financial capital is influenced by qualifications, competences and health condition. This conviction led in the 1960s to the formulation of the term human capital (Becker 1964). In the literature, a view was formed concerning the role of human capital as one of the most important factors in deciding on work productivity (both on the aggregate and individual levels), which then translates to increased economic innovation and a higher rate of economic growth (Benhabib, Spiegel 1994; Bassanini, Scarpetta, 2001). Human capital also positively impacts the development of regions – empirical studies show that those regions that decided to invest in human capital developed at a faster rate than others, regardless of the initial level of wealth (de la Fuente 2002).

The notion of social capital has been introduced in sociology (P.Bourdieu, J.Coleman) and economics to enrich the existing theories, especially the theory of economic growth (eg. Trigilia 2001, Blume, Sack 2008).

The success of contemporary economies and societies depends on their ability to create and absorb knowledge and innovation. Many researchers and experts believe that the effective use of production assets, infrastructure and financial resources is possible only with the appropriate level of human and social capital. Endogenous growth models highlight the fact that it is human capital that stimulates the diffusion of knowledge and technological development. Social capital, as opposed to human capital, is not an individual resource but occurs in relationships between individuals. It refers to the institutions, relationships and norms that shape the quality and quantity of a society's social interactions. Human and social capital, together with the institutional environment, are the three pillars of the human capacity to create wealth (Cote 2001).

The regional (spatial) disparity of human capital in Poland is the object of the numerous regional and local studies. The diversification of social capital in Poland according to the different levels of administrative division was analysed, among others, in papers by: Działek (2009, 2011) and Janc (2009). This study is the first in which the spatial and spatio-temporal relationships of those capitals levels are analysed. Presenting the results of this analysis is is the primary objective of this work. We can also indicate two detailed targets: constructing a composite indicator for both of the mentioned types of capital, as well as examining spatial interactions between human capital, social capital and GNP level per capita; this objective was achieved by means of the methods of the exploratory analysis of spatial data.

2. Human capital and social capital – basic terms and measures

Regional development, including its spatial disproportions, is the object of numerous regional and local studies. This is due to, among others, the policy of the European Union, which is aimed at the strengthening of regional economy.

Contemporary concepts of regional development refer to the new economic geography and the neoclassical models of growth. In the neoclassical models of growth, great importance is attached to the accumulation of knowledge in science and technology, and human capital. Following Becker, we may assume that this is the "whole of the activities, which impact the future monetary and physical income by increasing the resources within people".

An important feature of human capital is its uniqueness and multidimensional nature. The complex nature of this category is the reason why a uniform definition of the term human capital has not been worked out. However, there are recognised cognitive orientations which include the following approaches: income-related, cost-related and those relating to the human capital quality (Florczak 2006).

For the purpose of the presented studies, the OECD proposal was adopted, according to which "human capital is the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being," (OECD 2001).

This definition was also applied by the Central Statistical Office (GUS) of Poland (GUS 2010) for collecting data characterising human capital on the provincial (voivodeship) level in 2010. In the research carried out by GUS, the indicators were subjected to analysis describing human capital or having influence on its development. This concept was also applied in the presented analysis on the subregional level. The set of indicators available for the subregions is much narrower when compared to that proposed for the provinces. Given the limited availability of statistical data concerning the variables (indicators) which directly or indirectly characterise the resources of the human capital on the NUTS 3 level, the following concept was adopted to build the quality measure of human capital.

The following diagnostic variables were selected to account for various human capital aspects (in relation to the population):

education

- share of persons with tertiary educational level in the population in %,
- gross enrolment rate - post-secondary schools (aged 19-21),
- the number of university-level students,
- the number of graduates[1],
- computerisation rate in primary and lower secondary schools – number of computers with Internet access,

health (access to health care, health and prevention)

- life expectancy – males,
- life expectancy – females,
- expenditures of local government units on health care,
- number of medical consultations (out-patient health care),

demography

- demographic dependency ratio - the non-working age population per 100 persons of working age.

The above features served to build the composite indicator providing a comprehensive picture of human capital in the individual subregions.

Several significant variables being used in the studies on human capital such as concerning the B+R sphere are not available on the NUTS3 level.

We should also note that a condition for the high quality and value of human capital is the ability to use it effectively. It is emphasised that the quality of human capital is reduced by the inability of individuals to apply practically their knowledge and skills as well as by passive attuitudes and a lack of commitment to social issues.

Social capital is understood differently by different researchers. It is a multidimensional and multifaceted term, and a single recognised definition does not exist (Bartkowski 2007). In classical perspectives on social capital, two levels are analysed – those relating to individuals andthose to the community. This study presents a spatial analysis: administrative units on the NUTS4 level are compared within the whole country (Poland), and, therefore, the collective dimension of social capital was taken into consideration and it was treated as a feature of the territorial communities. Therefore, capital is understood as a resource for the whole community, from which benefits can be drawn by both the community as a whole and individual members. The closest to this understanding

[1] Statistical data concerning the number of graduate students are presented according to the actual location of the colleges/units – not residence. It does not reflect the actual situation well (it is only an approximation).

seems to be the definition by Coleman (1988), according to which social capital manifests in the co-operation of people within groups and organisations with the purpose to realise common interests. This co-operation is possible thanks to trust, observance of social norms, and the existence of networks and social organisations.

Many researchers consider crime and economic development as indicators of social capital, arguing that regions in which a high level of social capital resources occur should be safer and their economies better developed.

To construct the social capital measures, composite indicators are used based on the average standardised variables, ranking, graphs of standardised deviations from the average, main components' method. Alternative features utilised to construct composite indicators describe different dimensions of social capital (eg. the existence of social and organisational networks, security levels, voter turnout). Using that last feature is opposed by Portes (1998), who states that it does not participate in creation of social capital, but instead is its effect.

The analysis presented in this study was carried out on the subregional level (NUTS-3). The availability of statistical data on this level of aggregation is unsatisfactory. Among the indicators of social capital proposed in the literature, those listed below had statistical date available and were used. All features are expressed per 10,000 people. These indicators were used to construct the composite measures of:

- number of cultural centres, clubs and day rooms,
- number of events organised by a.m. entities,
- number of sports clubs,
- number of persons exercising in sports clubs,
- number of divorces,
- number of crimes committed, discovered in the completed preparatory proceedings,
- expenditures from the communities and districts budgets on security, culture and protection of national heritage and on physical culture.

The first two features testify to the effectiveness of the local self-government and cultural institutions it runs. Organised events provide the opportunity for meetings and contacts with other people living in a given area. Membership and activities in sports organisations contribute to increased confidence and involvement in social and political life. The number of crimes and number of divorces are known as destimulants, which means that an increase in their number negatively impacts the feeling of security on the family and public levels. Increased expenses from the budgets in the mentioned groups can contribute to the limitation of negative social phenomena (crime) and strengthened intensity of the activities of clubs, social-cultural and sports organisations.

The variable depicting the number of non-governmental organisations, although frequently mentioned and used in scholarship (eg., Janc 2009, Działek 2009) has not been used in this research because the data is missing on the NUTS-3 level. The same refers to voter turnout.

Composite indicators describing the level of human capital and social capital have been built as unweighted sums of the above-mentioned diagnostic variables after unitarisation:

$$Q_i = \sum_{j=1}^{K} z_{ij}, \tag{1}$$

where:

$$z_{ij} = \begin{cases} \dfrac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}} & \text{gdy } x_{ij} - \text{stimulant} \\[2ex] \dfrac{x_{j\max} - x_{ij}}{x_{j\max} - x_{j\min}} & \text{gdy } x_{ij} - \text{destimulant} \end{cases}$$

The higher value of the composite indicator means a higher level of human or social capital. The values for both measures are calculated for 2004 and 2012. The choice of 2004 was justified first of all by the fact that this was the year of Poland's accession to the European Union, and therefore possible changes in the spatial patterns of both variables or changes to their levels could reflect the influence of membership in this organisation. 2012 is the last period for which statistical data is available.

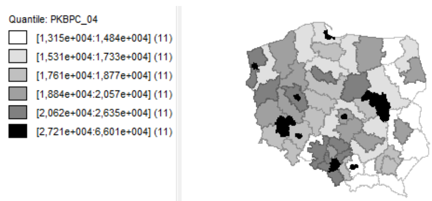
3. Spatial diversification of human and social capital

Graph 1 shows the spatial diversification of the GDP per capita, human capital and social capital. A concentration of high GDP values is noticeable in the subregions to which the largest Polish cities belong, and low values of the indicator occur predominantly in regions in the so-called Polish Eastern Wall.

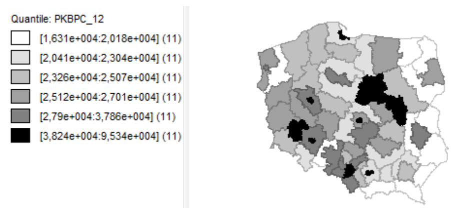
Moreover, we can see that in 2012 some subregions improved their condition, which is marked by darker colour on the map. The values of social capital show in the opposite way. We can see a concentration of high values of the composite indicators in the eastern subregions and, first of all, the south-eastern ones. In 2012, the number of subregions with the highest value of this feature (the darkest colour on the map) decreased. On the contrary, big cities are characterised by very low levels of social capital in both of the studied years. This result is certainly the effect of the selection of diagnostic variables in order to construct the capital measure. Because of the missing data, the number of non-governmental organisations, most dense in large cities, was passed over. On the other hand, when we take into account the number of activities, the number of cultural centres and day rooms favour rural areas with lively regional traditions or numerous ethnic minorities. The activities of the sports clubs is most intense in places where percentage of young people is highest.

Graph 1. Spatial diversification of the GNP per capita, human and social capital in the sub-regions

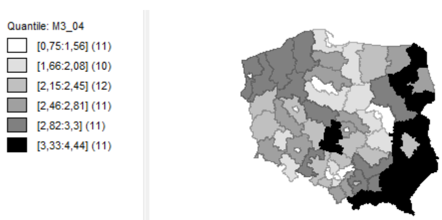
GDP per capita, (PLN, c.p), 2004



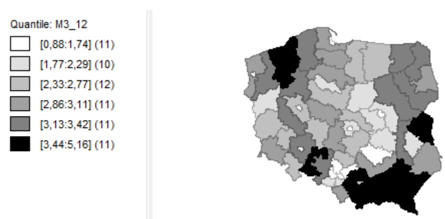
GDP per capita (PLN, c.p), 2012



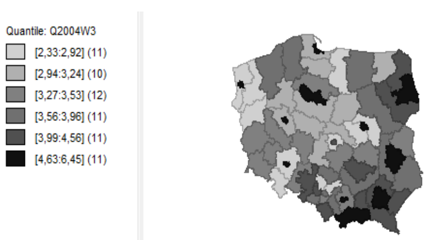
Social capital, 2004



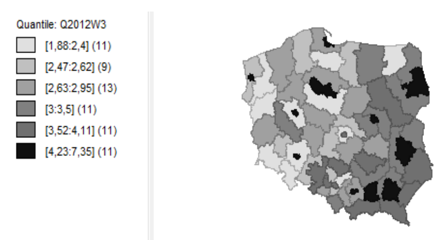
Social capital, 2012



Human capital, 2004



Human capital, 2012



Source: own elaboration based on GUS data.

Subregions containing big cities (Warsaw, Gdańsk, Szczecin, Wrocław, Kraków and Łódź) are the subregions with both high human capital as well as high GNP per capita. In 2012, we can observe an increase of the human capital level in subregions neighbouring the city of Warsaw subregion and the subregion bordering on the subregion of the city of Szczecin (subregions becoming alike).

The other subregions with high human capital include the subregions of Bydgoszcz-Toruń, Rzeszów, Białystok and Lublin.

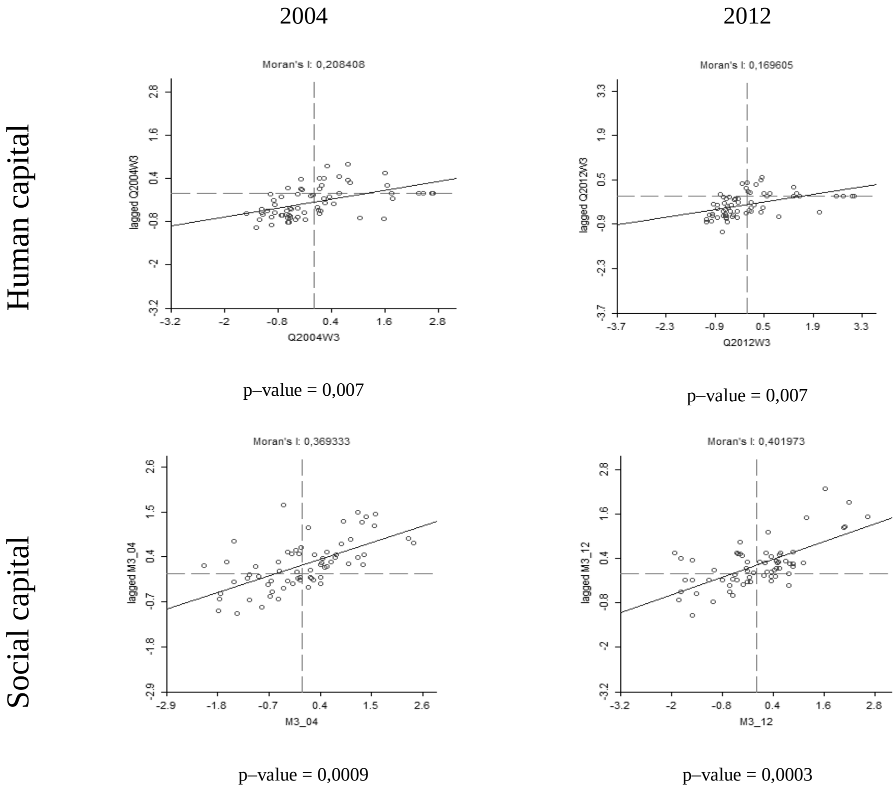
In the subregions with low levels of GNP located on the Eastern Wall, we can observe a relatively high level of human capital in both of the studied periods.

4. Relations in the shaping of human and social capital – one- and two-dimensional analysis

The first stage of the analysis was to examine whether spatial relationships occur in the shaping of human and social capital. Global spatial autocorrelation was tested using the Global Moran's I statistic, and local autocorrelation by calculating the LISA statistics. All of the statistics were calculated for the years 2004 and 2012.

Graph 2 shows the global Moran's I test results for human and social capital in the two years under analysis. In each case, the null hypothesis of the absence of spatial dependence in the human and social capital variables was strongly rejected. The Moran's I statistics show that the spatial clustering of high values (and/or low values) of both variables in the two analysed years is significant. The clustering is stronger for social capital, as the I-values are higher than for human capital. Furthermore, in the case of human capital we can see a concentration of values in the third quadrant (therefore negative), and in the case of social capital, the distribution between the first and third quadrants is more equinumerous.

Graph 2. Global Moran's I statistics for human and social capital

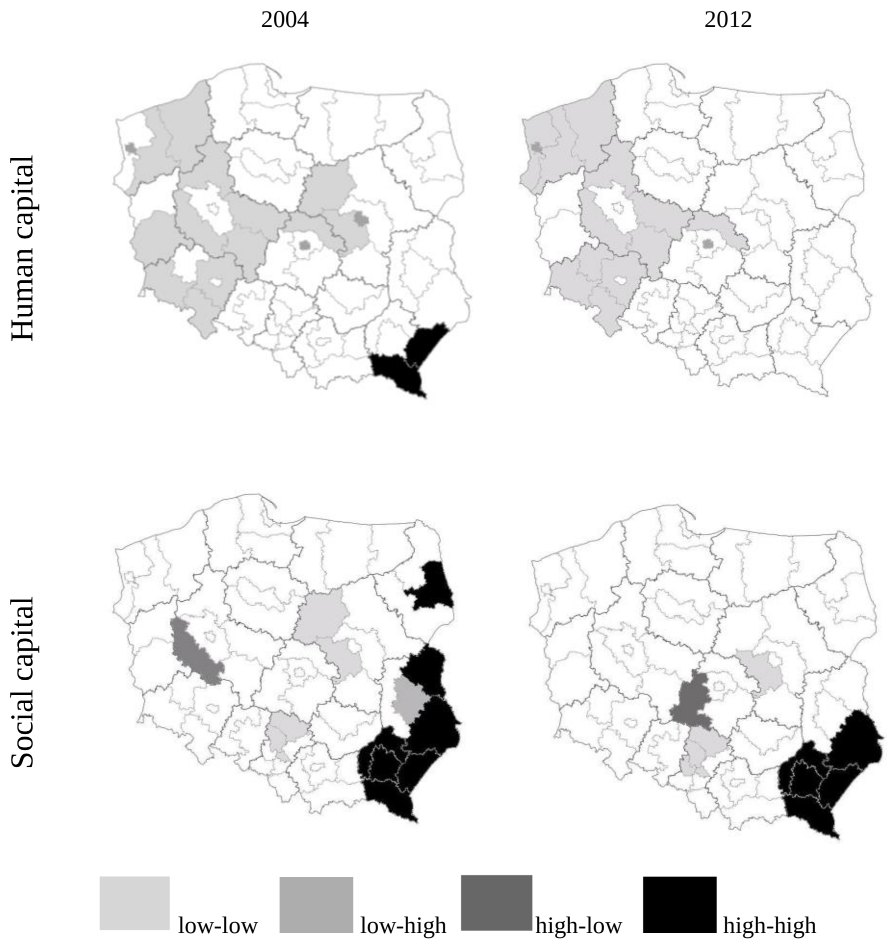


Source: own elaboration.

More detailed analysis can be done on the basis of local measures of spatial autocorrelations. This consists of studying the correlations of the variable value in the chosen location with its neighbours, and the results provide answer to the question of where precisely (in which part of the studied area) the spatial autocorrelation occurs. The values of Moran's Local Indicators of Spatial Association have been calculated and their graphic presentation is shown in Graph 3.

In the shaping of human capital values in 2004, the low – low types of relationships dominate, and therefore the subregions with low levels of human capital are concentrated in the areas of western Poland. Three cities, Warsaw, Łódź and Szczecin, are the so-called hot-spots or regions with high levels of human capital surrounded by regions with low levels. On the other hand, in 2012, the subregion of the city of Warsaw was no longer a hot-spot, which was due to the fact that the level of capital increased in the neighbouring subregions (see the map on Graph 1), yet not so much as to make the high – high type dependence statistically important. However, social capital shows the tendency for the clustering of positive values. Important relationships of the high – high type are noticeable in 2004 in the Podkarpacie region and near the eastern border, and in 2012 – only in Podkarpacie. Additionally, the range of the low values concentration decreases – for example, in 2012 it does not cover the Ciechanowsko–Płocki subregion, which could result from an increase of the capital value in the neighbouring Włocławek subregion. The hot-spot has moved from the Leszno subregion to the Sieradz subregion.

Graph 3. Local Moran's statistics for human and social capital



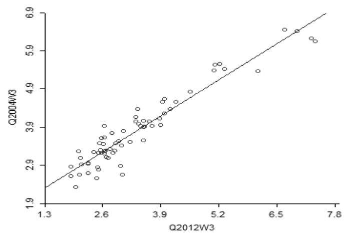
Note: only those subregions for which the statistical values are important on the level of least 0.05 are marked in colour.

Source: own elaboration.

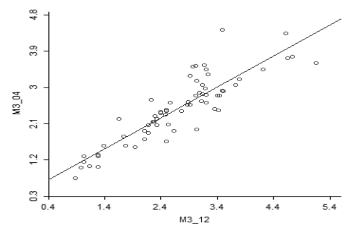
Based on a visual analysis of the Graphs 1 and 3, it seems that the spatial patterns shaping both types of capital are rather stable over time, which is additionally indicated by the correlation coefficients: r = 0.952 for human capital in 2004 and 2012 and r = 0.881 for social capital. To confirm this, an additional analysis was performed using the bivariate Moran's I statistics. Using the bivariate Moran scatter plot in combination with the usual Moran scatter plot and the correlation plot enables an analysis of the space-time correlation patterns for human and social capital in Poland's NUTS3 regions.

Graph 4. Space-time correlation patterns for human and social capital

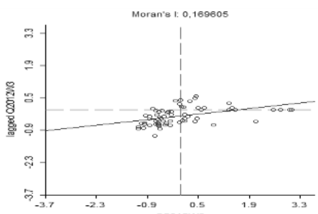
Human capital



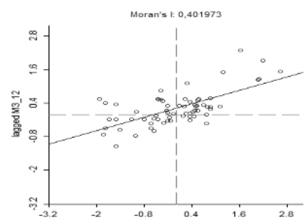
Social capital



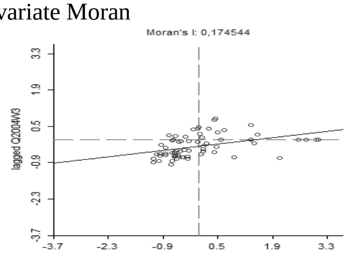
Moran I (2012)



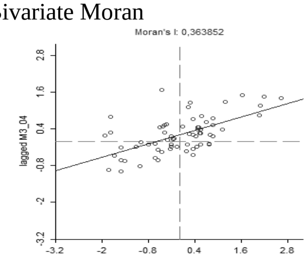
Moran I (2012)



Bivariate Moran



Bivariate Moran



Source: own elaboration.

The current measurement values in a given location are compared with the past values in neighbouring locations. In the case of both measures, the correlation is positive and is of high – high or low – low type. This means that between the years 2004 and 2012 no significant changes in the spatial patterns occurred in relation to human and social capital. In the case of social capital, the value of the bivariate Moran's I was 0.36, and for human capital it was 0.17, which means that stability of the distribution in time and space is stronger in case of social capital.

5. Human capital and social capital vs. GNPpc – an analysis of spatial relationships

The next stage of study was an analysis of the relations between human and social capital and the GNPpc level. Both local and spatial relations have been considered.

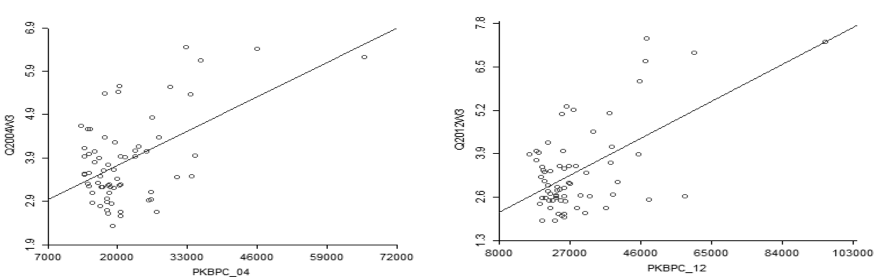
The correlation coefficients r = 0.57 for 2004 and r = 0.61 for 2012 show a positive relationship between the GDPpc and human capital in a given subregion. In 2012, the force of the relationship was slightly higher. This confirms the positive role of human capital in regional development.

However, the correlation coefficients of GNPpc with social capital in the studied years have negative values: r = -0.685 for 2004 and r = -0.631 for 2012. This result may be considered surprising because the literature hightlights the positive influence of social capital on economic development (economic growth, regional development). However, it is consistent with the conclusions resulting from the analysis of Graph 1, and it results from the choice of the diagnostic variables for the construction of the social capital measurement, in general, favoring the rural areas.

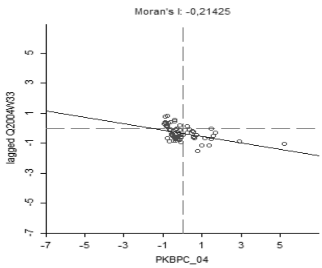
In the analysis of the spatial relationships between the GNPpc level and both types of capitals, bivariate Moran's I statistics were used, allowing an investigation of the relations between the GNPpc in a given region and the human capital or social capital in the neighbouring regions.

Graph 5. GDP per capita vs. human capital

Scatter plot, 2004 Scatter plot, 2012

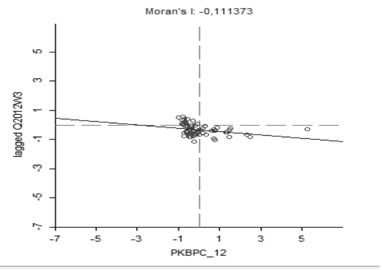


Bivariate Moran’s I (2004)



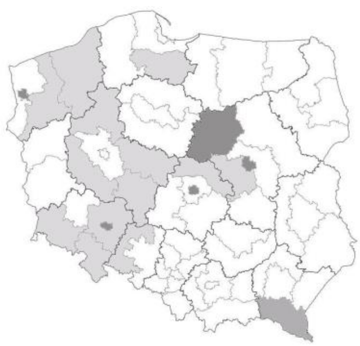
p–value = 0,001

Bivariate Moran’s I (2012)



p–value = 0,049

BiLISA cluster map (2004)



BiLISA cluster map (2012)

low-low low-high high-low high-high

Source: own calculations.

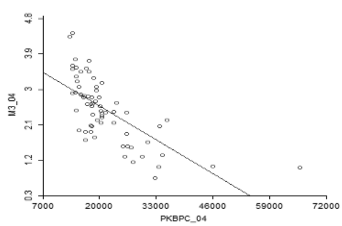
The values of the bivariate Moran’s I statistics for 2004 and 2012 indicate the existence of a negative spatial correlation between the GNP in a given region and the level of human capital in the neighbouring regions.

Relations of the low-low type are a definiate majority among the significant statistical spatial relations; these are subregions with low GNPpc are surrounded by subregions with low levels of human capital. There are a number of regions with high level of GNPpc which are surrounded by regions with low levels of human capital. In 2004, these were the Ciechanów-Płock subregion, the city of Warsaw, the city of Łódź and the city of Szczecin. In 2012, these subregions included the following: the city of Łódź, the city of Szczecin and the Wrocław subregion. Based on the obtained results, we can conclude that high levels of GNPpc characterising most of the mentioned subregions constituted the incentive causing the relocation of the human capital from the neighbouring subregions. It is worth adding that the results from 2012 should be treated with great caution (the pseudo p-value is close to 0.05).

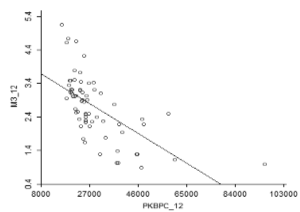
The value of the bivariate Moran's I statistics connecting GNPpc in the subregion with the social capital in neighbouring subregions, amounting in the studied years is, respectively, -0.2 for 2004 and -0.3 for 2012, indicating the existence of negative correlations. This is confirmed by the BiLISA results. Where significant, the correlation is of the low-high type: the low values of GDP is surrounded by high values of social capital. These subregions are situated in the east and south of Poland.

Graph 6. GDP per capita vs. social capital

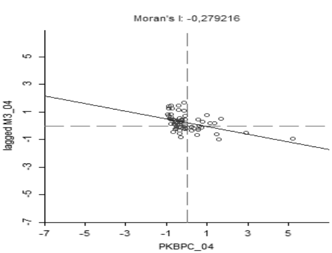
Scatter plot (2004)



Scatter plot (2012)

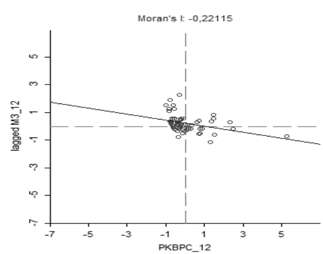


Bivariate Moran's I (2004)



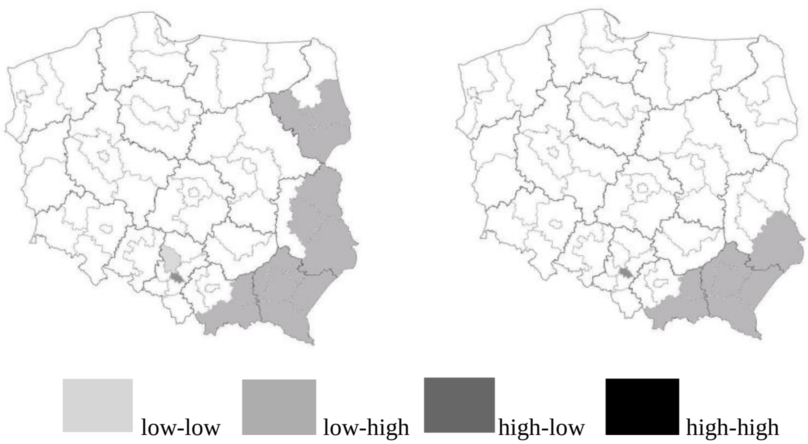
p-value= 0,002

Bivariate Moran's I (2012)



p-value=0,035

BiLISA cluster map (2004) BiLISA cluster map (2012)



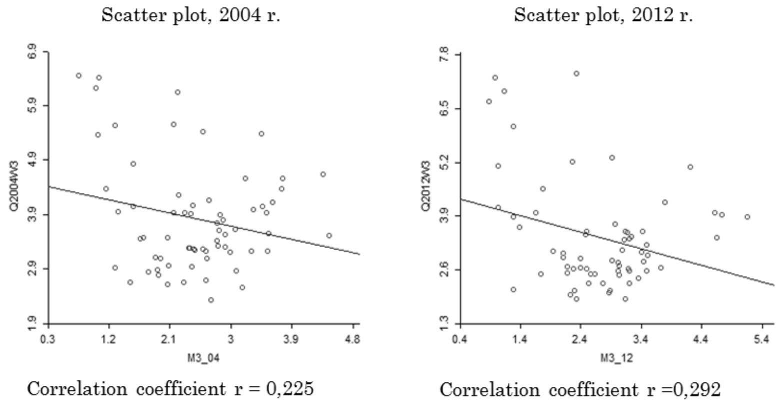
Source: own calculations.

6. Relationships between human capital and social capital in the subregions

The literature on this subject emphasises the mutual relatinships that connect social capital and human capital. On one hand, attention is drawn to the fact that in societies with higher levels of trust (social capital), individuals have greater propensity to invest in human capital (Knack Keefer 1997; OECD 2001). On the other hand, participation in education through the expansion of social networks and the intensification of social interactions and promotion of common standards supports the formation of social capital in a given society (Field 2005).

The relationship between social capital (horizontal axis) and human capital (vertical axis) in the Polish subregions in the analysed period is presented in Graph 7. The plots show a weak dependence between human and social capital. Great variation observed can be observed, as the values are highly scattered.

Graph 7. Human capital vs. social capital



Source: based on the authors' calculations.

A condition for the effective use of human capital is involvement in the social issues. In the analysed period, the correlation of both capitals in the subregions was not high, indicating that a high level of human capital is not associated with an equally high level of social capital. According to some authors (e.g., Kotarski, 2013), institutions and local leaders who are able to activate residents of a given local society to act have a great role to play.

7. Conclusions

In the studies on the competitiveness of regions, which can be defined as the ability to achieve success in economic competition, the importance of intangible factors is emphasised: human capital and social capital. The relationships between these factors and economic development on the regional level may differ from their interdependence in the national economy. Because the region differs from the national economy in that it cannot be characterised by significantly higher levels of openness enabling the easy migration of production factors, but mainly the migration of labor between the regions. This induces the conducting analyses of not only the local connections but also spatial relationships.

The presented studies confirm the large diversification of human and social capital measures in the subregions of Poland. Subregions containing big cities (Warsaw, Gdańsk, Szczecin, Wrocław, Kraków, Łódź) are the subregions with both high human capital measures and high GNP per capita. The analysis of data confirmed the positive correlation between the GNP level per capita and the human capital measure. The values of the correlation measures confirm the relationship between the discussed categories within a given subregion. However, the results of the spatial analysis show that some subregions with high level of development are surrounded by regions with low human capital and social capital.

The analysis confirmed the presence of spatial dependence in the formation of these variables. The one-dimensional analysis showed that measures of both types of capital exhibit spatial dependency. In the case of human capital, clusters of subregions with low levels of that measure are clearly observed. The spatial distribution of social capital is different. Subregions with the highest levels of the composite indicator are situated in the east and south of Poland, and measures of the local spatial correlation indicate groupings of subregions with high levels of social capital measures.

It is worth mentioning that the measurement of both phenomena – broadly understood human capital and social capital – is extremely difficult. Limitations in the scope of the data are caused in that many essential indicators are not available on the NUTS3 level, which may impact the obtained results. Despite these methodological weaknesses, it is worth using the idea of the human and social capital in regional analyses. Passing over such important factors may result in the insufficient explanation of some phenomena and processes.

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Streszczenie

WYBRANE NIEMATERIALNE CZYNNIKI ROZWOJU REGIONALNEGO. ANALIZA ZALEŻNOŚCI PRZESTRZENNYCH

Ponieważ przestrzenne zróżnicowanie rozwoju uznawane jest za jeden z podstawowych problemów współczesnych gospodarek, podejmowane są liczne próby określenia warunków i czynników kształtujących ten proces. Wskazywane są między innymi czynniki niematerialne: kapitał ludzki i kapitał społeczny (Herbst (red.), 2007).

Zasadniczym celem niniejszej pracy jest przestrzenna oraz przestrzenno – czasowa analiza zróżnicowanae poziomów kapitału ludzkiego i społecznego. Dwa cele szczegółowe to: skonstruowanie syntetycznych mierników obu wymienionych rodzajów kapitału, oraz zbadanie interakcji przestrzennych między kapitałem ludzkim i kapitałem społecznym a poziomem PKB per capita.

Stwierdzono znaczne zróżnicowanie poziomu kapitału ludzkiego i społecznego. Zauważono koncentrację podregionów o niskim poziomie kapitału ludzkiego, natomiast kapitał społeczny wykazuje tendencję do klastrowania się wartości dodatnich. Wykazano również występowanie dodatniej zależności między PKB per capita a poziomem kapitału ludzkiego, przy czym najwyższymi wartościami obu cech charakteryzują się największe miasta. Ponadto, występują podregiony dobrze rozwinięte gospodarczo (Łódź, Szczecin, Wrocław) otoczone niskimi wartościami kapitału ludzkiego i społecznego. Może to świadczyć o zjawisku wysysania przez te regiony kapitału z obszarów sąsiednich. Korelacja między PKB per capita i kapitałem społecznym jest w większości wypodków typu low-high. Podregiony, dla których to zjawisko występuje koncentrują się w Polsce wschodniej i południowej.

Słowa kluczowe: *kapitał ludzki, kapitał społeczny, rozwój regionalny, eksploracyjna analiza danych przestrzennych*

10.2478/cer-2014-0031

ARTUR GAJDOS*

Spatial Analysis Of Human Capital Structures

Abstract

The main purpose of this paper is to analyse the interdependence between labour productivity and the occupational structure of human capital in a spatial cross-section. Research indicates (see Fischer 2009) the possibility to assess the impact of the quality of human capital (measured by means of the level of education) on labour productivity in a spatial cross-section.

This study attempts to thoroughly analyse the issue, assuming that apart from the level of education, the course of education (occupation) can also be a significant factor determining labour productivity in a spatial cross-section.

The data used in this paper concerning labour force structure in major occupational groups in a regional cross-section comes from a Labour Force Survey. The data source specificity enables the assessment of labour force occupational specialisation at the regional level and the estimation of this specialisation at the subregional or county level.

An in-depth analysis of the occupational structure of the labour market in a spatial cross-section is an important theoretical and practical area of study necessary for the development of effective labour market policies and the education system.

Keywords: *labour market, occupational groups, labour productivity*

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1. Introduction

The main purpose of this paper is to analyse the interdependence between labour productivity and the occupational structure of human capital in a spatial cross section. Research indicates (see Fischer 2009) the possibility to assess the influence of the quality of human capital, measured by the level of education, on labour productivity in a spatial cross section.

The study attempts to thoroughly analyse the issue, acknowledging that it is not solely the level of education but also the course of education (occupation) likewise that may become a significant factor determining labour productivity in a spatial cross section.

This paper uses the data concerning labour force structure in major occupational groups in a province (NUTS2) cross-section, taken from a Labour Force Survey. The specificity of data source enables to assess a professional specialization of the labour force at a province (NUTS2) level and to estimate this specialization at the subregional (NUTS3) or county (NUTS4) level.

2. Specialisation and localisation by occupational groups

Analyses of the labour market occupational composition utilise the Polish Classification of Occupations and Specialisations congruous with the international ISCO-08 classification. The Polish classification is a hierarchical framework of occupational groups which currently identifies 10 major groups, 43 sub-major groups, 132 minor groups, 444 unit groups and 2366 occupations and specialisations.

The paper makes use of data from a Labour Force Survey across the provinces as well as the major and sub-major occupational groups. The table below presents the layout of the classification with names of occupational groups and their codes.

Table 1. ISCO-08 Code and occupational groups' names

ISCO 08 Code	Major group	ISCO 08 Code	Sub-major group
0	**Armed forces occupations**	01	Commissioned armed forces officers
		02	Non-commissioned armed forces officers
		03	Armed forces occupations, other ranks
1	**Managers**	11	Chief executives, senior officials and legislators
		12	Administrative and commercial managers
		13	Production and specialised services managers
		14	Hospitality, retail and other services managers

2	**Professionals**	21	Science and engineering professionals
		22	Health professionals
		23	Teaching professionals
		24	Business and administration professionals
		25	Information and communications technology professionals
		26	Legal, social and cultural professionals
3	**Technicians and associate professionals**	31	Science and engineering associate professionals
		32	Health associate professionals
		33	Business and administration associate professionals
		34	Legal, social, cultural and related associate professionals
		35	Information and communications technicians
4	**Clerical support workers**	41	General and keyboard clerks
		42	Customer services clerks
		43	Numerical and material recording clerks
		44	Other clerical support workers
5	**Service and sales workers**	51	Personal service workers
		52	Sales workers
		53	Personal care workers
		54	Protective services workers
6	**Skilled agricultural, forestry and fishery workers**	61	Market-oriented skilled agricultural workers
		62	Market-oriented skilled forestry, fishery and hunting workers
		63	Subsistence farmers, fishers, hunters and gatherers
7	**Craft and related trades workers**	71	Building and related trades workers, excluding electricians
		72	Metal, machinery and related trades workers
		73	Handicraft and printing workers
		74	Electrical and electronic trades workers
		75	Food processing, wood working, garment and other craft and related trades workers
8	**Plant and machine operators, and assemblers**	81	Stationary plant and machine operators
		82	Assemblers
		83	Drivers and mobile plant operators
9	**Elementary occupations**	91	Cleaners and helpers
		92	Agricultural, forestry and fishery labourers
		93	Labourers in mining, construction, manufacturing and transport
		94	Food preparation assistants
		95	Street and related sales and service workers
		96	Refuse workers and other elementary workers

Source: http://www.ilo.org/public/english/bureau/stat/isco/isco08/

Location quotients for major occupational groups in particular provinces (NUTS2) have been calculated in order to determine the specialisation and location of human capital (of the employed) across occupational groups (see Table 2).

Table 2. Location quotient[1] (LQ) by major occupational groups and provinces (NUTS2) in 2011 in Poland

NUTS2	Armed forces	Managers	Professionals	Technicians	Clerical workers	Service and sales workers	Agricultural workers	Craft workers	Operators	Elementary occupations
dolnośląskie	*0.48*	0.94	1.06	1.06	0.99	1.12	*0.45*	1.01	**1.28**	1.06
kujawsko-pomorskie	**1.75**	0.87	*0.75*	0.97	1.05	1.00	1.16	**1.22**	0.85	1.15
lubelskie	1.02	0.81	0.83	0.93	0.82	0.87	**2.32**	*0.79*	*0.68*	0.91
lubuskie	**3.04**	0.98	*0.80*	0.86	1.05	1.03	*0.35*	1.20	**1.25**	**1.77**
łódzkie	0.98	1.00	0.90	0.93	1.17	0.98	1.04	0.92	1.18	1.08
małopolskie	*0.40*	1.01	1.08	0.80	0.89	1.08	1.13	1.09	0.89	0.85
mazowieckie	1.12	1.14	**1.42**	1.14	1.14	0.87	0.90	*0.69*	*0.80*	0.87
opolskie	1.10	0.84	*0.77*	0.92	0.97	1.06	*0.74*	**1.27**	1.18	**1.32**
podkarpackie	0.95	*0.66*	*0.77*	0.95	*0.77*	0.93	**1.76**	1.05	1.15	*0.76*
podlaskie	*0.58*	*0.80*	0.83	0.83	0.85	1.04	**2.10**	0.86	*0.75*	0.85
pomorskie	**1.67**	0.99	1.11	1.16	0.99	1.02	*0.67*	1.06	0.94	0.88
śląskie	*0.12*	1.19	1.09	1.19	1.13	1.10	*0.24*	1.03	**1.24**	0.86
świętokrzyskie	*0.08*	1.01	*0.74*	*0.66*	*0.75*	0.84	**2.10**	1.13	0.83	0.99
warmińsko-mazurskie	**2.39**	0.92	0.81	1.09	0.87	1.05	*0.69*	**1.27**	1.06	1.18
wielkopolskie	0.91	1.08	0.86	0.89	0.96	1.03	0.95	1.16	0.99	1.19
zachodniopomorskie	**2.74**	1.01	0.84	1.05	1.02	1.15	*0.55*	1.08	1.06	**1.35**

(darker shade – localisation (specialisation), lighter shade – lack of localisation (specialisation)

Source: author's own calculations.

A brief analysis of the location quotient table leads to the conclusion that there exists a provincial specialisation in terms of occupation and that there occurs a concentration of people belonging to major occupational groups in particular provinces.

People employed within the Armed Forces occupational group (0) are most densely concentrated in the Lubuskie, Zachodniopomorskie and Warmińsko-Mazurskie provinces (LQ above 2). Conversely, they are least prevalent in the Świętokrzyskie and Śląskie provinces.

[1] A *location quotient* (LQ) is an analytical statistic that measures a region's specialisation relative to a larger geographic unit (see: Ekonometria przestrzenna, Suchecki B. (ed.) C.H.Beck, Warsaw 2010, p.135).

In the case of people categorised as employed in the managers group (1), clear location does not occur (merely a notable surplus in the Śląskie and Mazowieckie provinces). Provinces with a lower LQ for managers include Podkarpackie and Podlaskie.

For the professionals occupational group (2) it is the Świętokrzyskie and Kujawsko-Pomorskie provinces that have the lowest LQ. Professionals are more concentrated only in the Mazowieckie province.

Technicians and associate professionals (3) are not significantly concentrated in any province. Lower concentrations can only be observed in Świętokrzyskie province.

Similarly, with clerical suport workers (4) a lower location quotient is only true for the Świętokrzyskie and Podkarpackie provinces.

In the case of Service and Sales workers (5), it is impossible to pinpoint areas with an unusually high or low LQ – it is the occupational group characterised by the most even spatial distribution.

Skilled agricultural, forestry and fishery workers (6) are conspicuously concentrated in the following provinces: Lubelskie, Świętokrzyskie, Podlaskie (LQ over 2) and Podkarpackie (LQ of 1.76). Conversely, they are least prevalent in the Śląskie, Lubuskie and Dolnośląskie provinces (LQ below 0.5).

Craft and related trades workers (7) are located in the Opolskie, Warmińsko-Mazurskie and Kujawsko-Pomorskie provinces. It is the Mazowieckie and Lubelskie provinces that have low LQs for this group.

Plant and machine operators and assemblers (8) are concentrated in the Dolnośląskie, Lubuskie and Śląskie provinces, whereas they are less numerous in the Lubelskie, Podlaskie i Mazowieckie provinces.

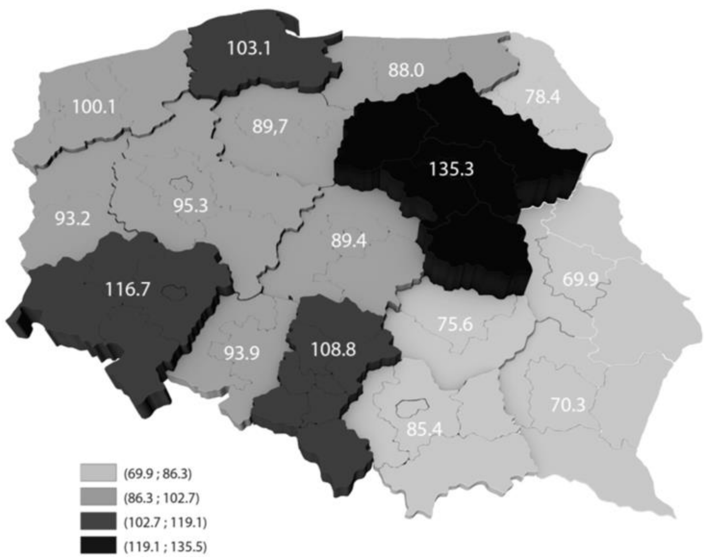
A high concentration of people belonging to the elementary occupations group can be observed in the Lubuskie, Zachodniopomorskie and Opolskie provinces, while the Podkarpackie province has a low LQ for this group.

An analysis of location quotients reveals that certain provinces specialise in specific occupational groups – the Mazowieckie province in the occupational group of professionals (2); the Dolnośląskie and Śląskie provinces in plant and machine operators and assemblers (8); the Lubelskie, Podkarpackie, Podlaskie and Świętokrzyskie provinces in skilled agricultural, forestry and fishery workers (6); the Kujawsko-Pomorskie and Warmińsko-Mazurskie provinces in crafts and related trades workers (7) as well as Armed Forces occupations (0); the Opolskie province in crafts and related trades workers (7) and elementary occupations (9); the Zachodniopomorskie province in elementary occupations (9) and Armed Forces occupations (0); the Pomorskie province in Armed Forces occupations (0). The Łódzkie, Małopolskie and Wielkopolskie provinces, on the other hand, do not possess occupational groups whose LQ exceeds 1.2 and thus lack specialisation.

3. Labour productivity and occupational structure

The next step involved conducting a comparative analysis of the relation between labour productivity (measured by means of Gross Value Added per employed person) and the occupational structure of the employed in terms of major occupational groups across provinces. The analysis was based on 2011 data due to the availability of regional accounts concerning Gross Value Added.

Figure 1. Gross Value Added (GVA) per employed person in 2011 NUTS2 (Poland=100)

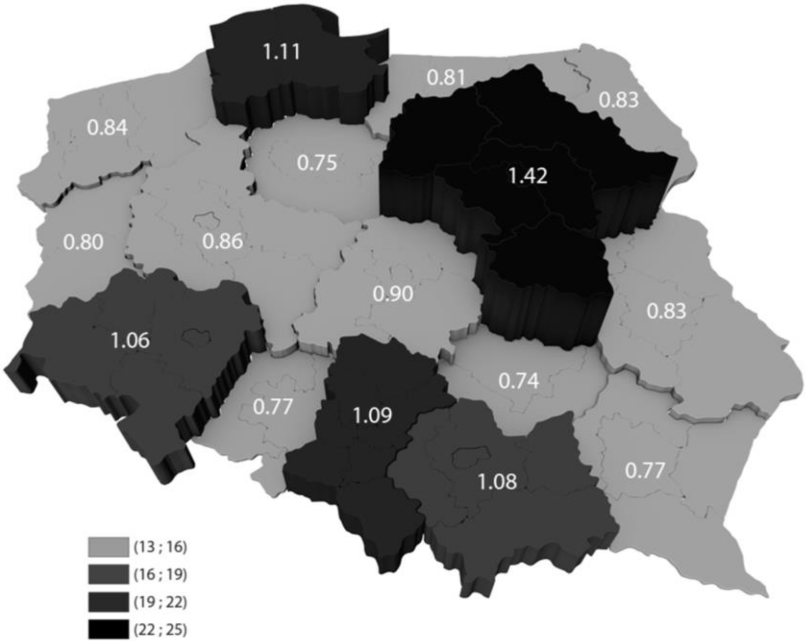


Source: author's own calculations.

The highest level of Gross Value Added per employed person (in relation to the country's average) in 2011 was reported in Mazowieckie (exceeding the country average by 35.3%). Other provinces with a value higher than the national average are Dolnośląskie, Śląskie and Pomorskie.

At the other extreme, with levels of GVA per employed person considerably below the country's average were the Lubelskie, Podkarpackie, Świętokrzyskie and Podlaskie provinces.

Figure 2. Share of Professionals (in %) and LQ (NUTS2) in 2011

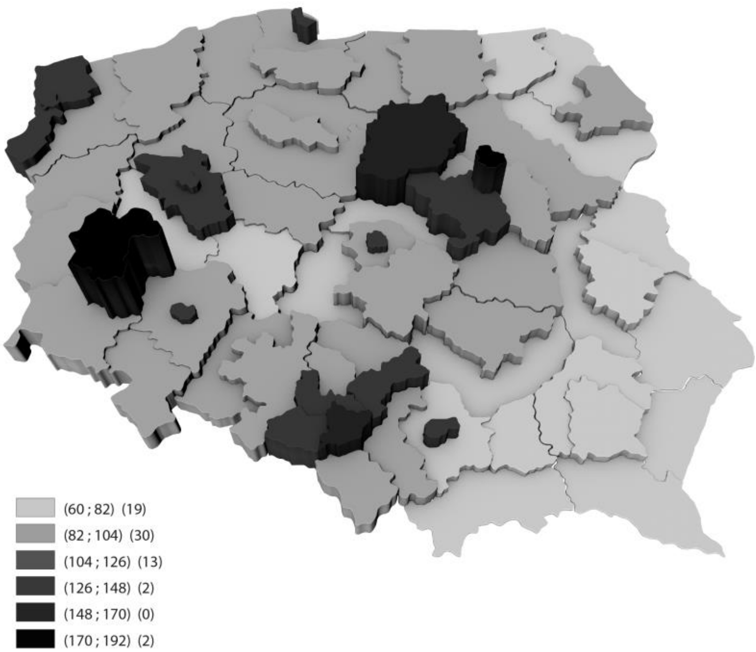


Source: author's own calculations.

The highest share (of people employed) in the occupational group of professionals (2) in 2011 was also recorded in the Mazowieckie province (LQ at 1.42). A high share of specialists (exceeding the country's average) was also reported in the Pomorskie, Śląskie, Małopolskie and Dolnośląskie provinces.

A lower share (well below the country's average) of people employed as professionals was recorded in all provinces with a conspicuously lower level of Gross Value Added per employed person (Lubelskie, Podkarpackie, Świętokrzyskie, Podlaskie) but also in the Kujawsko-Pomorskie and Opolskie provinces.

Figure 3. GVA per employed person in 2011 NUTS3 (Poland=100)



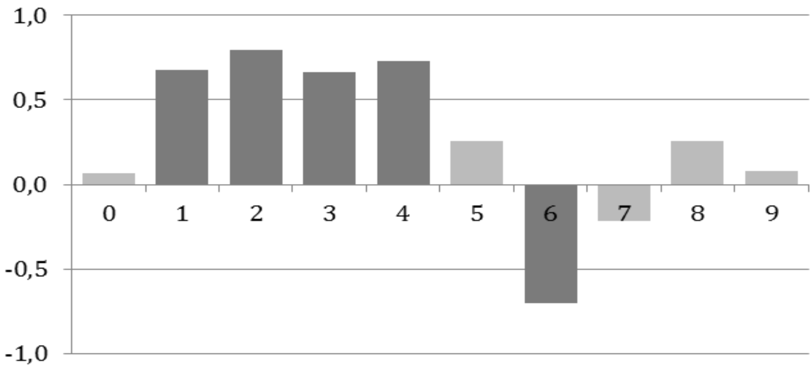
Source: author's own calculations.

An in-depth analysis of the level of Gross Value Added per employed person in the spatial cross-section indicates that the highest positive divergences from the country's average are found in the Legnica-Głogów subregion (copper mining area), the Warsaw subregion (capital city), the Tychy subregion (automotive industry), the Ciechanów-Płock subregion (petroleum industry). Values exceeding the average can also be observed in all subregions functioning as metropolitan areas.

The lowest level of GVA per employed person is found in the following subregions: Przemyśl, Krosno, Puławy and Chełm-Zamość, where agriculture is the dominating element of the region's economy.

The assessment of the strength of the correlation between the occupational structure of the employed and labour productivity in the provincial cross-section was conducted using the Pearson correlation coefficient.

Figure 4. Correlation coefficients (share of major occupational groups-GVA) NUTS2 in 2011



Source: author's own calculations.

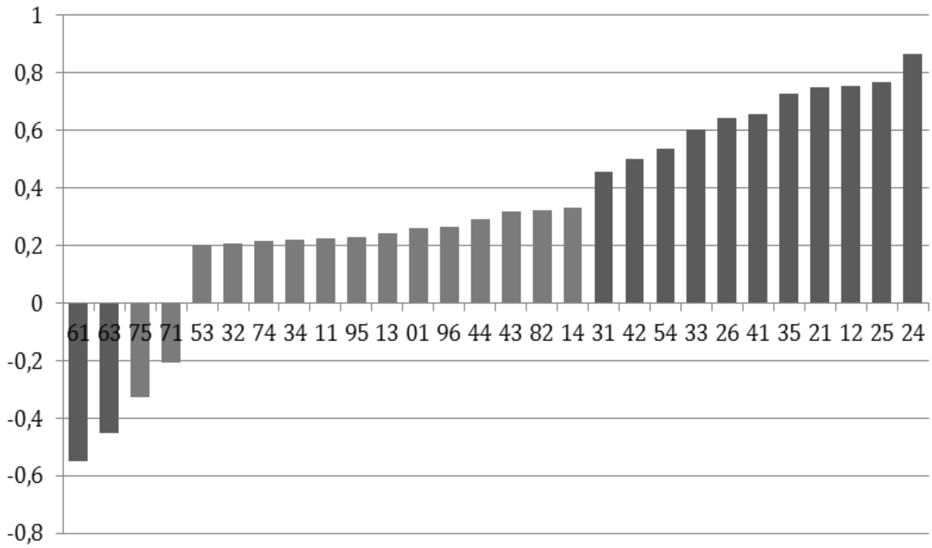
The highest positive value of the correlation coefficient determined for Gross Value Added per employed person and the share of the population employed in particular major occupational groups in the provincial cross-section was obtained for the major occupational group of Professionals (2). High values (of statistical significance) of the correlation coefficient were also observed for the following occupational groups: managers (1), technicians and associate professionals (3), clerical support workers (4).

A statistically significant negative correlation with Gross Value Added per employed person is present for those employed within the skilled agricultural, forestry and fishery workers group (6).

An in-depth analysis across the major occupational groups confirms a strong negative correlation (of statistical significance) for occupational groups associated with agriculture: market-oriented skilled agricultural workers (61) and subsistence farmers, fishers, hunters and gatherers (63). On the other hand, a noticeable positive correlation was observed for the following groups: business and administration professionals (24), information and communications technology professionals (25), administrative and commercial managers (12), science and engineering professionals (21), information and communications technicians (35), General and keyboard clerks (41), Legal, social and cultural professionals (26), business and administration associate professionals (33), protective services workers (54), customer services clerks (42), science and engineering associate professionals (31).

The chart below presents the values of correlation coefficients – statistically significant at the 5% level of significance (darker shade) and values ranging from 0.2 to -0.2 (lighter shade).

Figure 5. Correlation coefficients (share of sub-major occupational groups-GVA) NUTS2 in 2011



Source: author's own calculations.

4. Conclusions

The analyses conducted have confirmed the correlation between the occupational structure of the employed and the level of Gross Value Added per employed person in the provincial cross-section.

The highest influence on labour productivity in particular regions in this sense is exerted by the share of people employed within the occupational group of professionals (2). A positive influence (of statistical significance) has also been observed for the following occupational groups: managers (1), technicians and associate professionals (3), and clerical support workers (4).

The highest negative correlation was obtained for the share of major occupational group of skilled agricultural, forestry and fishery workers (6).

The share of people employed within the major occupational groups of Armed Forces occupations (0), service and sales workers (5), crafts and related trades workers (7), plant and machine operators and assemblers (8), elementary occupations (9) is not significantly correlated with Gross Value Added per employed person.

The analysis of correlations across the sub-major occupational groups facilitates the identification of areas capable of generating superior effects of labour force use. It is possible to indicate that outstanding labour productivity is mainly owed to the work of specialists and supporting groups. The aforementioned areas of high labour productivity comprise management (occupational groups 12, 24), engineering (occupational groups 21,31), ICT (occupational groups 25, 35), business support (occupational groups 26, 33, 41, 42, 54).

The results of analysis indicate that the highest labour productivity regions are characterised by a high share of employment in the following areas: management (staff, managers), engineering (engineers), ICT (computer scientists) and business services (lawyers, administration, customer service, security), which can be an important indication for educational policy (fields of study), labour market policies and supporting entrepreneurship.

The obtained results indicate a spatial diversity of labour productivity and the occupational structure of the employed. Intriguing results are also to be expected from detailed analyses, e.g. across occupational sub-groups (identification of occupational groups generating high labour productivity) or across subregions or counties (spatial analysis). However, due to shortage of statistical data, especially in the case of spatial analysis, such a venture is currently a tough challenge. An attempt at estimating the occupational structure of the employed populations across subregions (NUTS3) and counties (NUTS4) is the next step to be taken in this field.

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Streszczenie

PRZESTRZENNE ANALIZY STRUKTURY KAPITAŁU LUDZKIEGO

Głównym celem opracowania jest analiza zależności produktywności pracy i struktury zawodowej kapitału ludzkiego w przekroju przestrzennym. Badania wskazują (por. Fischer 2009) na możliwość oceny wpływu jakości kapitału ludzkiego mierzonego poziomem wykształcenia na produktywność pracy w przekroju przestrzennym.

W opracowaniu podjęto próbę pogłębionej analizy problemu zakładając, że poza poziomem wykształcenia znaczącym czynnikiem różnicującym produktywność pracy w przekroju przestrzennym może być kierunek wykształcenia (zawód).

W opracowaniu wykorzystano dane dotyczące struktury pracujących według wielkich grup zawodowych w przekroju wojewódzkim pochodzące z Badania Aktywności Ekonomicznej Ludności (Labour Force Survey). Specyfika źródła danych pozwala na ocenę specjalizacji (lokalizacji) zawodowej siły roboczej na poziomie wojewódzkim oraz szacowanie tej specjalizacji na poziomie podregionalnym lub powiatowym.

Pogłębione analizy struktury zawodowej rynku pracy w przekroju przestrzennym stanowią ważny teoretycznie i praktycznie obszar badań niezbędny dla prowadzenia efektywnej polityki rynku pracy i systemu edukacji.

Słowa kluczowe: *rynek pracy, grupy zawodowe, wydajność pracy*

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Transport Accessibility In Light Of The DEA Method

Abstract

The development of transport infrastructure and increasing the efficiency of transport services are major factors of economic growth. The concept of transport accessibility can be analysed in various aspects. This article focuses on the accessibility of freight transport by road and rail, measured with infrastructure equipment. The primary objective of this study is to determine the efficiency of selected European countries in 2000, 2005 and 2010 in terms of transport accessibility for given expenditures and results. The efficiency will be measured with the Data Envelopment Analysis, which assesses the efficiency with which a given economy transforms expenditures into results. The hypothesis assumes the existence of differences between the efficiency in terms of transport accessibility in European countries and a possibility to increase this efficiency by using the experience of countries with a high efficiency level.

Keywords*: transport accessibility, indicators of infrastructure, efficiency, DEA method*

1. Introduction

The development of transport infrastructure and increasing the efficiency of transport services are major factors of economic growth. The concept of transport accessibility can be analysed in various aspects. This article focuses on accessibility measured with infrastructure equipment, estimated with equipment

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indexes of a particular area with road and rail infrastructure. The primary objective of this study is to assess the efficiency of transport accessibility in selected European countries. The assessment is be carried out using the DEA method, which assesses the efficiency with which a particular economy transforms expenditures into results.

Transport infrastructure displays features of national wealth, while its accessibility and efficiency determine the development of each country through socio-economic activities. As a specialist factor, it determines new solutions, compatibility or interoperability, and provides a more stable and decisive basis for achieving competitive advantage (Załoga 2013, pp. 165–166). In addition, a well-developed transport infrastructure contributes to the reduction of the negative results of distance between regions, integrates the domestic market and connects it with markets of other countries and regions, as well as influences economic growth (through the quality and density of the network infrastructure) and reduces income inequality and poverty in a variety of ways (Schwab 2012).

The ongoing processes of globalisation and economic integration pose various challenges for economic policy, forcing policy makers to implement solutions that will improve economic efficiency and, consequently, to increase their competitiveness. The basic condition for the formulation of realistic objectives for transport policy is reliably identifying phenomena that determine the competitiveness of economies. As a result, the transport potential of particular economies is determined by many factors, both social and economic.

As an economic category, transport efficiency compares expenditures and results. The expenditures are all forms of resource consumption in the process of implementing transport policy goals and objectives. The results are benefits ensuing from transport policy implementation into socio-economic practises, e.g. increasing the number of people using transport infrastructure or improving the safety of the transport system. In the transport system, one can indicate the following relations between the incurred expenditures and achieved results (Janecki, Krawiec 2010, p.12):

- expenditures < results: the efficiency of the transport policy is positive
- expenditures = results: no major changes are identified in the transport system
- expenditures > results: the transport policy is not effective

The study covers the years 2000, 2005 and 2010, which were selected for comparison purposes. 25 European countries were selected for the analysis. Due to the lack of data, Cyprus, Malta, Norway, Switzerland and the countries of the former Yugoslavia were not included in the study.

2. The essence and problems of transport accessibility

The transport structure of a particular territorial unit is shaped by many various factors, giving rise to significant differences. The elements differentiating the transport system include, among others:

- geographical location
- degree of urbanisation
- location of industrial and tourist centres
- international co-operation
- level of technical and technological development

To analyse the transport situation, one must use a transport accessibility index, one of the key measures used to assess the transport system in spatial terms. The concept of transport accessibility is one of the key concepts in the planning of transport development in spatial terms. Transport accessibility can be used in various contexts, for example in relation to the transport network, various types of services, as a factor of economic development and competitiveness of the regions, and as a factor in business location (Koźlak 2012, p. 172).

The word "accessibility" is derived from the words "access" and "ability", which means getting access to something. As a result, the term refers to the degree of ease with which the inhabitants of a given area can gain access to goods, services and places of activity (e.g, employment, education, health, etc). The degree of accessibility can be defined as the sum of distances to all other locations or on the basis of the number of direct and indirect connections available with the use of various modes of transport. The starting point for the analysis of transport accessibility is a quantitative and qualitative assessment of transport infrastructure in terms of the density of the network and transport points, capacity or speed limit (Koźlak 2012, pp. 173–174).

Transport accessibility has an impact on the relative benefits of a given region associated with the decisions taken relating to investment locations. As a result, accessibility may be analysed using a variety of indexes (Rosik 2012, pp. 23–24):

- infrastructure-based accessibility - estimated with the use of the indexes of the equipment of a particular area with transport infrastructure, such as the number/density of linear and point objects (road network, railway stations, Park &Ride car parks, airports, etc.)
- distance-based accessibility - physical distance (Euclidean), actual physical distance (road), time distance (travel time, transit time) and economic distance (cost of travel, cost of transport) between the starting point and the

destination, e.g. the average cost of travel to cities above 100.000 inhabitants, the total travel time to the 10 largest cities in Europe

- cumulative accessibility (isochronic accessibility) - measured by assessing a set of destinations available at a given time, with a specified traveling cost or traveling effort, e.g. population available within 15 minutes, number of hospitals available within 1 hour
- person-based accessibility - based on the so-called time geography associated with individual socio-economic characteristics of the participants in the movement in time and space, as measured by the so-called daily paths of life,
- potential accessibility - measured by the possible occurrence of an interaction between the starting point of the travel and a set of travel destinations (one assumes that with the increased time or cost of travel, the attractiveness of the destination decreases, as the traveller is more willing to travel for shorter distances).

In addition, Table 1 shows indexes of transport accessibility divided into groups and types.

Table 1. Transport accessibility indexes

Group indexes	Type of index	Examples of index
Indexes describing the transport infrastructure and supply of services	Indexes of equipment of a region with transport infrastructure	- the length and density of various roads and railways - density of roads and railways weighted with the population - the number of airports and seaports
	Indexes of linear and point infrastructure capacity	- capacity of road, railways, inland waterways - capacity of road junctions, ports and airports of different categories, intermodal terminals
	Indiexes of supply of transport services	- volume of supply - number of arriving/leaving means of transport by mode and direction - number of passenger cars, means of public transport and freight transport by type - transport duration - the cost of transport
	Indexes of susceptibility of infrastructuredamage	- susceptibility of the infrastructure components of the transport corridors to damage due to the geographical location and climate
Indexes of location accessibility expressed in the function of transport time or cost	General	- cities which can be reached within a certain time - average time to reach all European metropolises - daily transport accessibility - potential transportaccessibility - daily accessibility by car or train

	Access to transport infrastructure	- access to the motorway, railway station, airport / seaport
	Access to places of activity	- the average time to reach to the 3 nearest cities over 100,000 inhabitants - time to reach to cities with a population of 200,000 inhabitants - time to reach the nearest Europeanmetropolisby truck - travelling time by air between European metropolises - daily access of European metropolises
Innovative mapping solution	Maps showing relationship between transport and space	- maps showing the time distance - anamorphic spatiotemporal maps and transport costs maps

Source: Koźlak A. (2012) Nowoczesne systemy transportowe jako czynnik rozwoju regionów w Polsce, Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk, p. 178.

The essence of complex transport accessibility indexes is the fact that they take into account spatial interactions (i.e. travelling distance, time and cost). One can assume that the attractiveness of a particular region increases with transport accessibility and decreases with the increasing distance, time or cost of travel. It should also be mentioned that regions equipped with rich transport infrastructure are able to attract more investors, compared to the regions which are poor in this respect. Moreover, the development of transport infrastructure and increase of the efficiency of transport services, occurring thanks to the improved efficiency of this particular branch of industry, is one of the important factors of economic growth.

3. Analysis of the efficiency of European countries

Efficiency is the result of activities undertaken as described by the relation between the achieved results and incurred expenditures. The best effects of production, distribution, sales and promotions are the subject of numerous discussions and analyses. One can also talk about the efficiency of an organisation, manager, management, use of possessed resources or undertaken investment projects.

One most frequently considers efficiency when undertaking investment activities and comparing various investment options, looking for one that will bring the best effect. Efficiency is measured using partial, synthetic indexes of resource productivity (labor, capital), and can be identified in terms of ex-post and ex-ante. When calculating ex-ante efficiency, one assesses the expected results with the involvement of particular resources and time. The ex-post efficiency consists of determining the results of specific activities. In general, one uses a ratio analysis to assess efficiency.

The efficiency of entities, undertaken projects, transport systems and processes can be assessed with standard methods used in the analysis and audit of financial statements, the evaluation of their condition and the efficiency of investment undertakings.

In this analysis, the Data Envelopment Analysis (DEA) was used. The DEA classical result-oriented model was applied to obtain the results (Guzik 2009, p. 22). Therefore, if the model is focused on results, the results are maximised while expenditures are reduced. The mathematical programming model takes the following form:

$$\theta = h_i(\mu, \vartheta) = \frac{\sum_{r=1}^{R} \mu_r y_{ri}}{\sum_{p=1}^{P} \vartheta_p x_{pi}} \rightarrow max \qquad (1)$$

with the limits:

$$\frac{\sum_{r=1}^{R} \mu_r y_{ri}}{\sum_{p=1}^{P} \vartheta_p x_{pi}} \leq 1, \mu_r \geq 0, \vartheta_p \geq 0 \qquad (2)$$

where: h_i - the effeciency of object (i = 1, …, n), y_{ri} - results, x_{pi} - expenditures, μ_r - weight corresponding to particular results (r = 1, …, R), ϑ_p - weight corresponding to particular expenditures (p = 1, …, P). If the model is focused on expenditures, one minimises expenditures with a lower limit on the results.

To use the DEA method, one has to meet some important requirements which have an impact on the quality and correctness of the achieved results (Guzik 2009, pp. 27–29):

- the set of objects must be homogeneous or almost homogeneous
- the results and expenditures should be non-negative
- the measurement units should be uniform
- the direction of preferences should be uniform, i.e. the quantity considered to be the result must be defined in a way that enables the positive evaluation of its growth in terms of the purpose of the activity of the analysed objects, while the quantity considered to be the expenditure should be defined in a way enabling one to evaluate its growth in negative terms
- expenditure is a quantity with which at least one result is connected.
- the number of objects should be much larger than the total expenditures and results.

The DEA method has many advantages. For example it gives one an opportunity to study objects described with multiple expenditures and multiple results. Furthermore, DEA does not require very specific information, as opposed to index-based or econometric methods. With this method, one can determine the relationships between global expenditures and global results. Using DEA, one can to determine the efficiency with which a multi-dimensional system of expenditures is transformed into a multi-dimensional system of results. Thanks to DEA, expenditures and results do not need to be expressed in monetary units (Guzik 2009, p. 29).

One should also mention the disadvantages of the DEA method, which is characterised by the results' high sensitivity to atypical data in objects recognised as models. If the model object is an atypical one, the results of the analysis of the efficiency of other objects are considerably less credible. One may also notice a negative impact on the test results of surprising and unstable results in the case of a strong correlation and linear relationships within the results, within the expenditures or between the results and the expenditures. The disadvantage of this method is also the redundancy of the number of efficient objects, especially in its traditional versions, and a poorly-developed theory of nonlinear relationships between the expenditures and the results. Another disadvantage may be the relative nature of the object's efficiency. In the DEA method, efficiency is determined against the background of other objects. As a result, an object with a relatively low efficiency may be considered fully efficient because the other objects are worse. The opposite scenario is also possible (Guzik 2009, p. 30).

4. Characteristics of the analysed objects

This study covered selected European countries in the years 2000, 2005 and 2010, in order to observe changes in efficiency in terms of transport accessibility. The study utilised the mid-year data from the European Commission report "Energy and Transport in Figures 2013". Variables expressed by the dynamics index, which provide information about the changes of a given phenomenon in time, were also applied. In the analysis, five-year time intervals were used. The imperative aim is to determine whether the countries perform implement the transport policy in an efficient way. In the analysis, a set of expenditures (variables characterising the linear infrastructure and means of transport) and results (variables characterising the result in the form of transport work) characterising the freight road and rail transport accessibility were used.

Figure 1. List of expenditures and results in terms of transport accessibility

EXPENDITURESS	→	RESULTS
•increases in the road networks **•increase in the number of trucks** **•increases in the rail network** **•increase in the number of freight locomotives**		• increase in road transport work • increase in rail transport work

Source: author's own.

The level of transport accessibility in European countries varies, as different countries are characterised by different economic, social, demographic, geographic and political conditions. In this study, the main attention is focused on the accessibility of freight transport by road and rail. The following variables were chosen to characterise this phenomenon: highway length, railway length, number of motor vehicles (road and rail transport) and transport work. The following maps show density indexes, the automotive indexes and transport work. The darkest colour on the map suggests that the level of the variable in a given country is highest in comparison to other countries. The lightest colour suggests that the level of the variable in a given country is the lowest, compared to other countries (white indicates a lack of data).

The density of highways in 2000, 2005 and 2010 in the European countries increased, which is a positive phenomenon. Germany, Denmark, Italy and the Benelux countries stand out in terms of this variable.

Figure 2. The density of the highway network in km per 100 sq km in 2000

Source: author's own study based on "EU Energy and Transport in Figures 2013".

Figure 3. The density of the highway network in km per 100 sq km in 2005

Source: author's own study based on "EU Energy and Transport in Figures 2013".

Figure 4. The density of the highway network in km per 100 sq km in 2010

Source: author's own study based on "EU Energy and Transport in Figures 2013".

The railway network is the densest in the following European countries: the Czech Republic, Belgium, Luxembourg and Germany. This does not mean that the remaining countries do not use this means of transport. In recent years, rail transport has been gradually developing as an alternative to road transport.

Figure 5. The density of railway network in km per 100 sq km in 2000

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

Figure 6. The density of railway network in km per 100 sq km in 2005

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

Figure 7. The density of railway network in km per 100 sq km in 2010

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

The number of trucks in the European countries has been increasing year after year. The following maps show that France, Spain, Portugal, Denmark and Greece had the highest number of trucks per 100 inhabitants in 2000. Poland, Finland and Ireland could also boast a large number of trucks in 2010.

Figure 8. The number of trucks per 100 inhabitants in 2000

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

Figure 9. The number of trucks per 100 inhabitants in 2005

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

Figure 10. The number of trucks per 100 inhabitants in 2010

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

The number of freight locomotives per 100 inhabitants in the analysed time varied. A decrease in this type of rolling stock was observed in Finland, Bulgaria and Latvia, whereas an increase was recorded in Germany and Belgium.

Figure 11. The number of freight locomotives per 100 inhabitants in 2000

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

Figure 12. The number of freight locomotives per 100 inhabitants in 2005

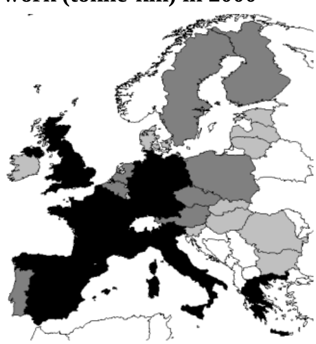
Source: author's own study based on the "EU Energy and Transport in Figures 2013".

Figure 13. The number of freight locomotives per 100 inhabitants in 2010

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

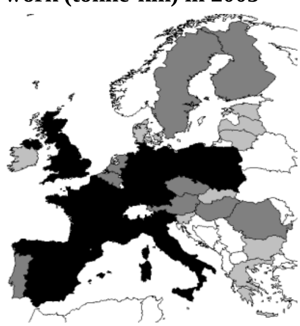
Road transport work in European countries in 2000, 2005 and 2010 has been on the increase. A quite significant increase in the road transport work can be observed in Poland when compared to other European countries. In Austria, on the other hand, a decrease in road transport work in 2010, as compared to 2005, was recorded.

Figure 14. Road transport work (tonne-km) in 2000



Source: author's own study based on the "EU Energy and Transport in Figures 2013".

Figure 15. Road transport work (tonne-km) in 2005



Source: author's own study based on the "EU Energy and Transport in Figures 2013".

Figure 16. Road transport work (tonne-km) in 2010

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

The volume of national railway transport work was much lower than the volume of the road transport work. The highest values were recorded in France, Germany and Poland.

Figure 17. Rail transport work (tonne-km) in 2000

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

Figure 18. Rail transport work (tonne-km) in 2005

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

Figure 19. Rail transport work (tonne-km) in 2010

Source: author's own study based on the "EU Energy and Transport in Figures 2013".

5. Results

The following measures of efficiency for selected European countries in terms of transport accessibility take the values above 1 or the value of 1. Efficient economies achieve the value of 1, which means that they optimally transform expenditures into results. Meanwhile, countries for which the measure of efficiency is higher than 1 are inefficient and do not use their expenditures in an optimal way.

Table 1. Effeciency index in terms of transportaccessibility for the European countries in 2000

COUNTRY	**BE**	**BG**	**CZ**	**DK**	**DE**	**EE**
THETA	1,92149	1,56085	2,16733	1,91551	**1**	**1**
COUNTRY	**IE**	**EL**	**ES**	**FR**	**IT**	**LV**
THETA	1,17233	**1**	1,74375	1,38378	1,58352	**1**
COUNTRY	**LT**	**LU**	**HU**	**NL**	**AT**	**PL**
THETA	**1**	**1**	1,78954	2,01215	1,27303	1,63228
COUNTRY	**PT**	**RO**	**SI**	**SK**	**FI**	**SE**
THETA	2,06738	**1**	1,58318	2,3274	1,84107	1,86904
COUNTRY	**UK**					
THETA	**1**					

Source: author's own study.

Table 1 shows the results of efficiency measurements for the year 2000. Germany, Estonia, Greece, Latvia, Lithuania, Luxembourg, Romania and Great Britain are the countries which effectively used their expenditures in terms of transport accessibility (100% expenditures were transformed into results). The other analysed countries did not use the expenditures to the full extent. The results achieved by Slovakia should have been higher by 133% when its expenditures are taken into account. The results indicate that Slovakia should become similar to Estonia by 59% and to Lithuania by 40% in order to achieve better results. Other countries which did not use their expenditures properly include: Portugal (107%), Czech Republic (117%) and the Netherlands (101%). Ireland came closest to achieving efficiency (its results should have been about 17% higher than its expenditures). Ireland should become similar to Latvia in order to increase its efficiency in terms of transport accessibility.

Table 2. Effeciency index in terms of transport accessibility for European countries in 2005

COUNTRY	BE	BG	CZ	DK	DE	EE
THETA	1,41523	**1**	1,68493	1,44215	**1**	**1**
COUNTRY	**IE**	**EL**	**ES**	**FR**	**IT**	**LV**
THETA	1,98899	**1**	1,38192	1,45524	1,4888	**1**
COUNTRY	**LT**	**LU**	**HU**	**NL**	**AT**	**PL**
THETA	**1**	2,0103	1,41303	1,07874	**1**	1,48117
COUNTRY	**PT**	**RO**	**SI**	**SK**	**FI**	**SE**
THETA	**1**	**1**	1,18177	1,00923	1,55015	**1**
COUNTRY	**UK**					
THETA	1,93599					

Source: author’s own study.

Table 2 shows the efficiency indexes for the year 2005. In 2005, the following European countries achieved 100% efficiency in terms of the transport accessibility: Bulgaria, Denmark, Germany, Greece, Lithuania, Latvia, Austria, Portugal, Romania and Sweden. This means that these countries fully used the expenditures intended for transport accessibility, achieving the maximum results. Luxembourg was much below the limit of efficiency. It should have had about 101% higher results at the given expenditures. Luxembourg should increase its efficiency in terms of transport accessibility by becoming similar to such countries as Latvia, Lithuania and Romania. Slovakia almost reached the efficiency level in 2005. The results show that it was only inefficient by 1% in terms of transport accessibility.

Table 3. Effeciency index in terms of transport accessibility for the European countries in 2010

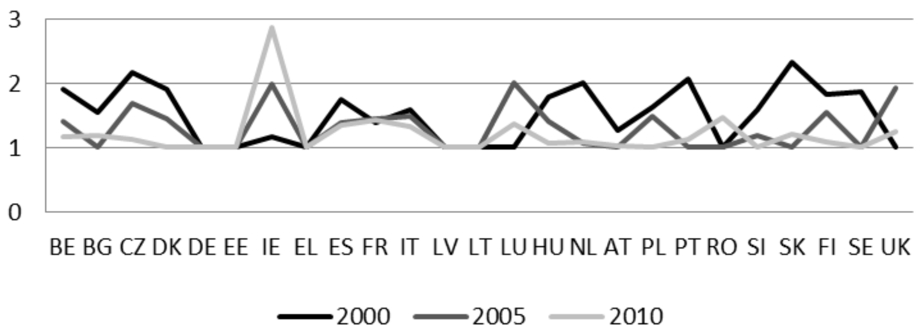
COUNTRY	BE	BG	CZ	DK	DE	EE
THETA	1,17639	1,19048	1,12942	**1**	**1**	**1**
COUNTRY	**IE**	**EL**	**ES**	**FR**	**IT**	**LV**
THETA	2,87868	**1**	1,3545	1,42704	1,33045	**1**
COUNTRY	**LT**	**LU**	**HU**	**NL**	**AT**	**PL**
THETA	**1**	1,36927	1,07197	1,08959	1,02664	**1**
COUNTRY	**PT**	**RO**	**SI**	**SK**	**FI**	**SE**
THETA	1,1237	1,46737	**1**	1,2161	1,08059	**1**
COUNTRY	**UK**					
THETA	1,25618					

Source: author’s own study.

Table 3 presents the results of efficiency in terms of transport accessibility in 2010. Countries which efficiently used their expenditures in the transport accessibility in 2010 include Denmark, Germany, Estonia, Greece, Lithuania, Latvia, Poland, Slovenia and Sweden. The least efficient country was Ireland, which should have had 188% higher results than those actually achieved in 2010. The analysis shows that in order to achieve higher efficiency Ireland should become similar by 87% to Poland and by 13% to Greece (the best practises for transport accessibility should be derived from countries such as Poland and Greece). Austria was at the limit of efficiency (its results should have been about 2% higher at the given expenditures). Austria should become similar to countries such as Denmark, Lithuania, Poland and Sweden. Finland was also close to achieving efficiency (8%). In terms of transport accessibility, it should become similar to Germany (by 31%), Lithuania (by 14%) and Sweden (by as many as 52%).

Figure 20 shows the changes in the efficiency index in the selected European countries in 2000, 2005 and 2010. Over the years, one can see that the group of countries characterised by model efficiency of transport accessibility has not increased. One can only notice that some countries were characterised by high efficiency in one analysed period and low efficiency in another analysed period. It should also be noted that in the case of 10 countries, one can observe improved efficiency in terms of transport accessibility. In the case of Romania and Ireland, an increase of the theta value was recorded, and hence there was a deterioration in their efficiency, i.e. usage of expenditures in an inefficient way. It should also be noted that in all analysed years, countries such as Germany, Estonia, Lithuania and Latvia achieved 100% efficiency in terms of transport accessibility. Germany has a very well-developed structure of road and rail networks, so its high efficiency in terms of transport accessibility comes as no surprise. In contrast, Estonia, Lithuania and Latvia are characterised by a poorer transport system. However, the specified countries use their expenditures in the best way. Consequently, their efficiency index is at the level of 1.

Figure 20. Efficiency index of transport accessibility in European countries in the years 2000, 2005 and 2010



Source: author's own study.

6. Conclusions

Differences in the level of the accessibility of freight land transport in European countries are caused by the varying popularity of particular modes of transport. In addition, these countries also vary in economic, geographic, environmental and social terms. The results of the analysis of efficiency in terms of transport accessibility in the European countries can be considered as satisfactory. For most countries, one can see a certain variability in time, which may result from changes in transport policy conducted both by the national governments and by the European Union (of which most of the analysed European countries are members).

The DEA method allows one to reach some interesting conclusions. Therefore, the application of this method in this analysis should be considered justified. The advantage of the DEA method is that there are no requirements regarding the form of the function expressing the relationship between the expenditures and the results. The variables describing the expenditures and results can also have different denominations. A positive aspect of the application of the DEA method are also the results specifying objects to which a particular object should become similar if it wants to increase its efficiency. On this basis, the governments of particular countries may want co-operate in the conducting of transport policy. Countries with high efficiency could prepare a catalogue of good practises in transport operations for countries that would like to improve their efficiency.

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Streszczenie

DOSTĘPNOŚĆ TRANSPORTOWA W ŚWIETLE METODY DEA

Rozwój infrastruktury transportu i wzrost sprawności obsługi transportowej jest jednym z istotnych czynników wzrostu gospodarczego. Pojęcie dostępności transportowej można rozpatrywać w różnych aspektach. W niniejszym artykule skupiono uwagę na dostępności towarowej drogowej i kolejowej mierzonej wyposażeniem infrastrukturalnym. Podstawowym celem opracowania jest określenie efektywności wybranych krajów Europy w 2000, 2005 i 2010 roku pod względem dostępności transportowej przy danej liście nakładów i rezultatów. Badanie efektywności zostanie przeprowadzone na podstawie analizy DEA (ang. Data Envelopment Analysis), której przedmiotem jest ocena efektywności, z jaką dana gospodarka transformuje posiadane nakłady na wyniki. Hipoteza zakłada, że istnieją różnice pomiędzy efektywnością pod względem dostępności transportowej w krajach europejskich oraz możliwe jest podniesienie analizowanej efektywności poprzez wykorzystywanie doświadczeń krajów, które charakteryzują się wysokim poziomem efektywności.

Słowa kluczowe: *dostępność transportowa, wskaźniki infrastruktury, efektywność, metoda DEA*

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Health Inequalities Across The European Union Regions: A Beta-Convergence Approach[1]

Abstract

The European Union is currently facing a serious problem concerning the occurrence of significant health inequalities observed between particular member states as well as within these states. Substantial efforts are being made to achieve an economic and social cohesion and the reduction of health inequalities between the EU regions is an important element of this process.

This work is devoted to the study of the variations of health status (measured by life expectancy) across the EU regions of NUTS II level. We apply existing tools developed in economic growth literature to study a mortality convergence. Using the idea of unconditional convergence model developed for economic growth, we can confirm a decrease or increase of regional health inequalities. The main research hypothesis is as follows: whether regions with lower initial life expectancies have experienced the largest increases in life expectancies. To verify the hypothesis of beta-convergence we use spatial econometric models which additionally allow to take the geographic dependence among the surveyed regions into consideration. Due to the heterogeneity of the surveyed spatial units we also verify the hypothesis of the club beta-convergence.

Keywords*: health inequalities, club convergence, beta-convergence, European Union regions*

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1. Introduction

The issue of public health has been present in the European Union since its very beginning and has been gradually growing in importance. Although the average population health status has been improving on a continuous basis for the last few decades, the differences in health status between the inhabitants of various EU regions and between groups in the most advantageous and disadvantageous social situation still remain substantial, and in some cases they have even increased (Commission of European Communities 2009).

Therefore, the European Union is facing a serious problem consisting in the existence of significant health inequalities both between its member states and within these states. The differences in health status are influenced by several socio-economic factors. The economic conditions affect the living conditions in various ways, which in turn affects the health status.

To reduce health inequalities, the UE has undertaken activities detailed in the EU policy instruments - strategic documents and health programs. The most important ones include:

- the Europe 2020 strategy (through the promotion of a permanent economic growth and social cohesion);
- the 'Together for Health" strategy: a strategic approach towards the EU for 2008-2013";
- the "Health for Economic Growth" program (2014-2020);
- Communication from the Commission "Solidarity in health: reduction of health inequalities in the EU" (2009);
- EU cohesion policy.

The main goal of our study is an assessment of the existence of convergence of health status across the EU regions. First, we apply economic growth theory to study health status convergence using two frameworks of convergence studies: an unconditional beta-convergence model and a two-regime convergence model for a club-convergence process.

Secondly, we extend the conventional econometric approach for beta-convergence model to a spatial econometric framework. If regional data are used in regression framework, one has to take into consideration a spatial autocorrelation (Anselin 1988, p.57; Fingleton 2003; Eckey et.al. 2006, p. 2). Spatial convergence models allow one to take into account relations existing between the analysed regions and the impact of a particular region on the neighbouring regions.

Conclusions drawn from the conducted analyses may provide guidance and valuable instructions for the pursuance of regional and health policies at the EU level. Their practical application by relevant institutions at the central (EU) and regional levels could contribute to a better use of the structural funds, to the improvement of health protection systems and, ultimately to the improvement of the health status of the inhabitants - especially in the regions with the most difficult economic and social situation.

2. The literature review

A significant number of papers have been dedicated to study regional income convergence. The beta-convergence approach proposed by Barro and Sala-i-Martin (1990, 1992) is the most frequently used one. Beta-convergence has been studied in many papers. The convergence hypotheses were advanced by Solow (1956) and documented by Baumol (1986) and Barro and Xavier-Sala-i-Martin (1995). However, spatial econometric approach has been applied to regional convergence in recent years (cf. Baumont et.al. 2003; Fischer and Stirböck 2006; Eckey et.al. 2006).

The issue of health inequalities, due to the growing importance of this problem, is being dealt with not only in the EU policies and programs, but it also raises interest among the scientists. From the point of view of the EU cohesion policy, growing regional disparities in public health status lead to both theoretical and empirical in-depth research. The issue of health inequalities occurs quite frequently in the literature. The population health status is a complex and difficult to measure category. One of the best widely available indicators of public health is life expectancy. To show that life expectancy can be modelled using the theory of economic growth, there must exist close association of health with income and growth (Mayer-Foulkes 2001). The crucial study in this field is Preston (1975) paper, in which he has indicated that LE is positively correlated with income. For instance, Barro (1991) has found life expectancy indicator to be an important variable of economic growth model. Arora (2001) has found cointegration between economic growth and health in 100-125 year time series for seven advanced countries.

To analyse health inequalities some researches use sigma-convergence approach based on a variance tendency (cf. Edwards and Tuljapurkar 2005). Decrease in a dispersion (e.g. measured by the standard deviation or variation coefficient) over the period means that regions converge. In a different approach Gini coefficient is used as a measure of dispersion (c.f. Peltzman 2009; d'Albis et.al. 2006).

In recent years we can also find some papers devoted to the reduction of regional health inequalities with applying a beta-convergence methodology. The topic of club-convergence has been explored by Mayer-Foulkes (2001). He analysed convergence clubs in cross-country life expectancy dynamics. Life expectancy was modelled in terms of physical and human capial and technology, the basic economic variables described by economic growth theories. On the international scale also one can find research into the convergence of the public health status on the local level (Gächter and Theurl 2011).

One of the recent works, which is a contribution to the literature on convergence in health status, is a paper by d'Albis et.al. (2012). Authors have applied econometric tools commonly used in the economic growth literature to assess the existence convergence across high-income countries. They used both sigma- and beta-convergence methods.

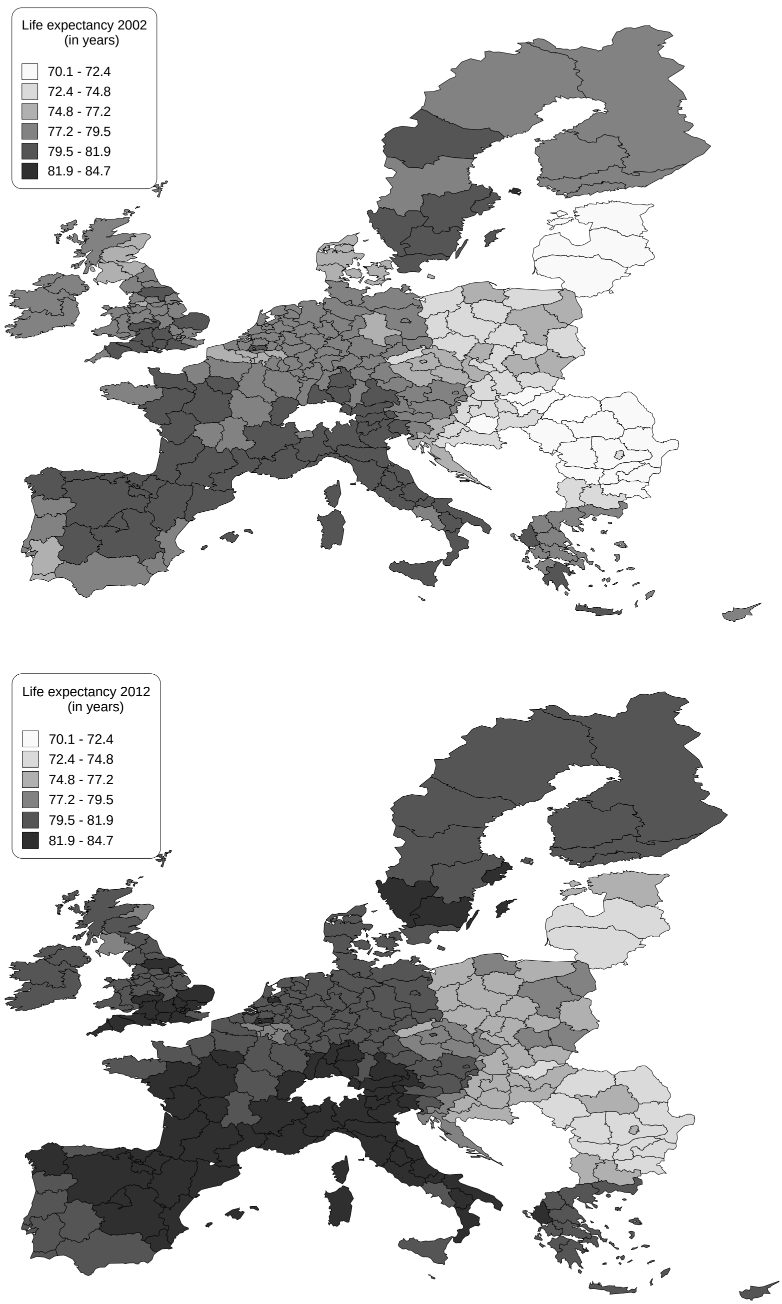
From among the Polish researchers Jankowiak (2010) attempted to assess the convergence - only in relation to the health protection systems in the EU countries. Other recent Polish works explain the evaluation of the European Union regional convergence (see Markowska and Strahl 2012).

3. The database

We use data for the years 2002-2012 at the NUTS-2 level for all European Union countries. This data came from Eurostat and the ISTAT (Italian National Institute of Statistics – data for Provinces of Emilia-Romagna and Marche). When choosing the spatio-temporal scope, one was guided by the criterion of data availability and comparability. A period of time longer than the indicated one, would allow one to better determine the occurrence of certain trends, especially those in the social sphere. However, this would impose a spatial limitation on the analysis. Thus changes in the NUTS classification (e.g. in the case of Germany, Italy, and Croatia), and in particular, changes in the boundaries, merger and separation of new subregions, were taken into account by recalculation of the variable values, according to the NUTS classification in 2010. Generally, we examine regional convergence of 265 regions in 28 EU countries:

Austria (9), Belgium (11), Bulgaria (6),Croatia (3), Czech Republic (9), Cyprus (1), Denmark (5), Estonia(1),Finland (5), France (22), Germany (38), Greece (13), Hungary (7),Ireland (2) , Italy (21), Latvia (1), Lithuania (1), Luxemburg (1), Malta (1),the Netherlands (12), Portugal (5), Poland (16), Romania (8), Slovak Republic (4), Slovenia (2), Spain (16), Sweden (8), UK (37). Some islands (e.g. French overseas Departments, Canary Islands (Spain), Madeira, Azores (Portugal) have been excluded.

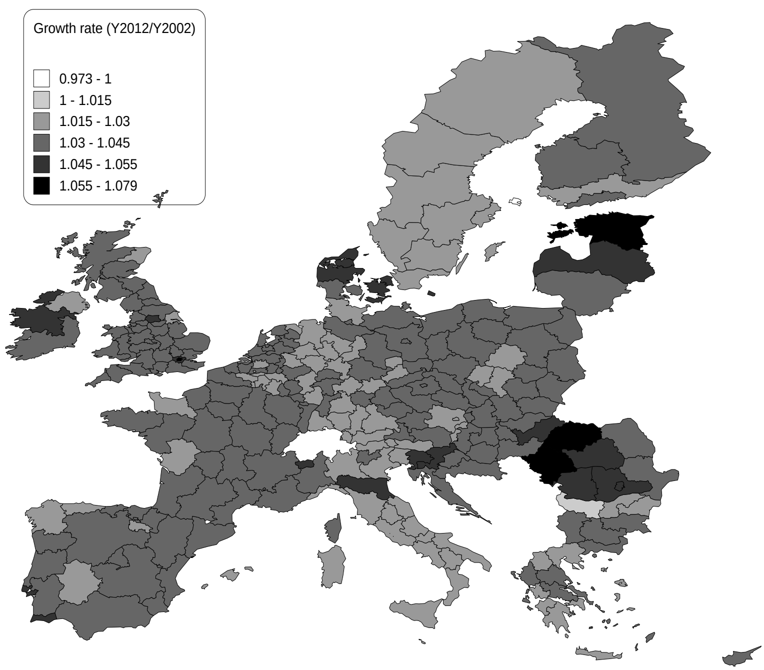
Figure1. Life expectancy at birth in 2002 and 2012



Source: own elaboration based on the Eurostat and ISTAT data.

The regional distribution of life expectancy (in two selected years – 2002 and 2012) is displayed in Fig. 1. The distribution of the variable, as one can expect, is spatially differential. The lowest values of life expectancy are characteristic particularly for the new member states: Bulgaria, Romania and also Poland, Lithuania, Latwia and Estonia. Besides, we can see some clusters of high and low values of the variable, which can indicate a spatial autocorrelation process.

Figure 2. Life expectancy growth rate between 2002 and 2012



Source: own elaboration based on Eurostat and ISTAT data.

Generally regions with lower initial state for life expectancy (especially some regions of Eastern Europe) have achieved greater increases. It can point to a convergence process.

4. Methodology

Income convergence refers to the situation in which relatively poorer regions grow faster than their rich counterparts. In its strongest version (known as absolute convergence), an implication of this hypothesis is that, in the long run, countries or regions should not only grow at the same rate, but also reach the same income per capita. Convergence can be conditional (conditional beta-convergence) or unconditional (absolute beta-convergence). Conditional convergence implies that a country or a region is converging to its own steady state while the unconditional convergence implies that all countries or regions are converging to a common steady-state.

To analyse the dynamics in health inequalities Barro-style methodology for convergence analysis was used. The unconditional β-convergence model can be formally expressed by formula (Kusideł 2013, pp. 47-49):

$$ln\left(\frac{y_{ito+T}}{}\right) = a + bln(y_{it0}) + u_{it0.t0+T}, \tag{1}$$

where: Y_{it0} – the final level of log-normal *per capita* GDP*;* Y_{it0+T} – the initial level of log-normal *per capita* GDP; T – interval between observations of the dependent variable during the initial and final year.

There is absolute beta-convergence when b is negative and statistically significant, where b parameter is estimated as:

$$b = -(1 - e^{-\beta T}), \tag{2}$$

To measure the speed at which the steady-state is approached it is used a convergence rate given by:

$$\beta = -\frac{ln(1+b)}{T}, \tag{3}$$

Given the convergence rate β, we can easily calculate half distance to steady state (half-life) that may be obtained by the below given formula:

$$hl = -\frac{ln2}{\beta}, \tag{4}$$

Adapted for life expectancy the absolute beta-convergence equation, has a following form:

$$ln\left(\frac{s_{ito+T}}{}\right) = a + bln(s_{it0}) + \mu_{it0.t0+T}, \tag{5}$$

s_{it0} - life expectancy values in logarithms for *i*-region in initial year .

s_{it0+T} - life expectancy values in logarithms for *i*-region in final year;

We consider two types of models with spatial interactions:

1. The case of Substantive Spatial Dependence (spatial lag model):

$$\boldsymbol{g} = \alpha \boldsymbol{S} + \rho \boldsymbol{W} \boldsymbol{g} + \varepsilon, \tag{6}$$

where: $\boldsymbol{W}$- (n,n) spatial weight matrix (euclidean distance-based), $\boldsymbol{g} = \left(\frac{s_{it0+T}}{s_{it0}}\right)$- $(n,1)$-vector of growth rate of life expectancy over the given time period, **S** – vector of observations on life expectancy variable in logarithms in initial year, ρ – spatial autoregressive parameter, $\boldsymbol{\varepsilon}$ – error term.

2. The case of Spatial Error Dependence (spatial error model):

$$\boldsymbol{g} = \alpha \boldsymbol{S} + \varepsilon, \tag{7}$$

$$\varepsilon = \lambda \boldsymbol{W} \varepsilon + \boldsymbol{\mu}. \tag{8}$$

where: **g, W, S** are defined as before, $\boldsymbol{\mu}$ – $(n,1)$ is a vector of errors, λ is an autoregressive parameter in the error dependence model.

European regions are different because of economic and social level, the differences are large especially between old and new Member States. When we have a heterogenous sample, one need to cluster regions to smaller group called clubs. To test club convergence we estimate a spatial regime model proposed by Baumont et. al. (2003, p. 146) written as follows:

$$ln\left(\frac{s_{ito+T}}{s_{ito}}\right) = a_1 D_1 + a_2 D_2 + b_1 D_1 ln(s_{it0}) + b_2 D_2 ln(s_{it0}) + \varepsilon \tag{9}$$

$$\varepsilon \sim N(0, \sigma^2, I)$$

where: D_1, D_2 – dummy variables describing two spatial regimes previously defined. D_1 equals to 1 if region *i* belongs to club A and 0 if region *i* belongs to club B. D_2 equals to 1 if region i belongs to club B and 0 if belongs to club A;

$\left(\frac{s_{ito+T}}{s_{ito}}\right)$ - life expectancy growth rate beetwen final year and initial year;

s_{it0} - life expectancy values for *i*-region in initial year.

5. Discusssion

In the literature there are several methods to analyse convergence clubs. In the recent European convergence studies researchers define convergence clubs with ESDA techniques.[2] This allows you to identify clusters of neighbouring regions with high and low values of the variable ("hot spot" and "cold spot"). For instance, Fingleton (2003) use global indicators of spatial association (Moran's *I* statistic). Some researchers employ local indicators (LISA) (Baumont et. al. 2006) such as Getis and Ord's (G*) statistic (see Fischer/Stirböck 2006).

We use Moran's *I* statisitic to identify spatial regimes in the data according to Baumont et. al. (2003). The statistic of Moran *I* coefficient (Moran 1950) is defined as:

$$I = \frac{N}{S_0} \frac{\sum_i \sum_j w_{ij} (y_i - \bar{y})(y_j - \bar{y})}{\sum_i (y_i - \bar{y})^2} \tag{10}$$

where: where N is the number of spatial units indexed by i and j, $\bar{y}$ is the mean of the y variable, w_{ij} are the elements of the weight matrix W*, and S_0 is the sum of the elements of the weight matrix: $S_0 = \sum_i \sum_j w_{ij}$. The expected value of Moran's I is defined as:

$$E(I) = -\frac{1}{N-1} \tag{11}$$

If I > E(I) we have positive spatial autocorrelation. For our study area (265 regions) E(I) equal -0,0038. Values of the Moran's *I* statistic are shown in table 1.

Table 1. Moran's I statistic based on life expectancy variable in all surveyed years

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
I	.618	.616	.640	.637	.638	.638	.626	.637	.639	.632	.633

Source: own calculations.

Moran's *I* points to possible positive spatial autocorrelation in all surveyed years. Broadly speaking, a positive spatial autocorrelation means that high values of the variable are neighbouring high values and low with low. The resuls are clusters of regions: low-low values, high-high values, low-high and high-low.

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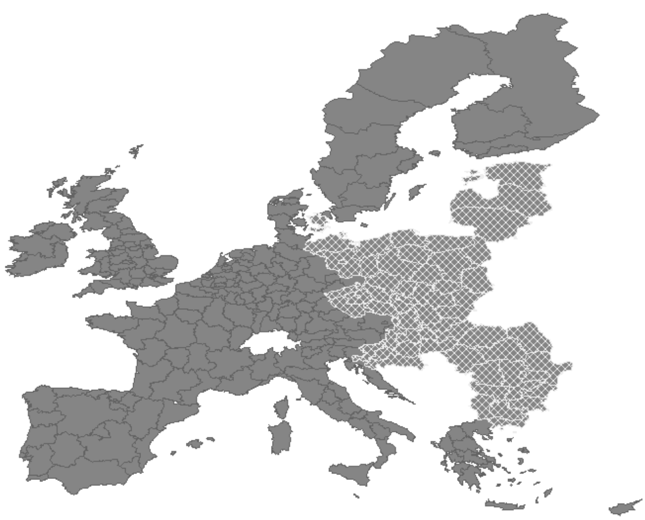
[2] Anselin (1994) define ESDA (Exploratory Spatial Data Analysis) as the collection of techniques to describe and visualise spatial distributions, identify atypical locations (spatial outliers), discover patterns of spatial association (spatial clusters), and suggest different spatial regimes and other forms of spatial instability or spatial non-stationarity.

Figure 3. Spatial regimes in the initial (2002) life expectancy by Moran's scatter plot

Club A (H-H quadrant of Moran scatterplot)

Club B (L-L quadrantof Moran scatterplot)



Source: own elaboration based on the Eurostat and ISTAT data using euclidean distance-based weight matrix.

Figure 3 shows a spatial distribution of two defined spatial regimes – Northwest regime (Club A) and Eastern regime (Club B). The 157 EU regions are located in H-H quadrant of Moran scatterplot, 59 regions are located in L-L quadrant and 49 other regions are of type L-H and H-L, which means no spatial dependence. Since these 49 regions have been excluded, our new sample includes 216 regions which belong to the Club A (H-H) and Club B (L-L). We noticed a polarization pattern across the EU regions in view of life expectancy. This polarization pattern is strongly similar to income polarization between rich regions in the north and poor regions in the south (see Fingleton 2003, p. 131).

The next step was an empirical analysis beginning with the ordinary regression model (5). Firstly we have estimated stationary model by Ordinary Least Squares for the entire sample (see first column of Table 1). The estimated coefficient b indicates that life expectancy variable in initial year ($\ln S_{2002}$) is significant with appropriate sign on the coefficient estimate. It shows that beta-convergence has taken place in the period 2002-2012, which means regions with lower lower initial life expectancy have obtained the largest increases in life expectancies.

Table 1. Estimation results of unfiltered stationary model

	OLS		**ML (lag/error)**	
	coefficient	t-value	coefficient	z- value
a (constant)	0,48***	8,54	0,39***/0,65***	5,36/7,99
b ($\ln S_{2002}$)	-0,10***	-7,97	-0,087***/-0,14***	-5,29/-7,59
λ(spatial error)			0,63***	5,66
ρ (spatial lag)			0,39***	3,03
converg. speed (annual)	1,05%		0,91% / 1,6%	
half-life	66 (years)		76 / 46 (years)	
Diagnostic measures	R^2 = 0,19		R^{*2} = 0,22/0,27	
	Log likelihood = 932,36		Log likelihood = 936,7/943,9	
	AIC criterion = 1860		AIC criterion = -1867/-1883	
	Moran *I* = 0,13***			
	LM (error) = 42,89***			
	Robust LM (error) = 45,12***			
	LM(lag) = 13,15***			
	Robust LM (lag) = 15,37***			

*Significant at the level of 0,1; **Significant at the level of 0,05; ***Significant at the level of 0,01

Source: own calculations.

Estimation of the rate of convergence is above 1 percent per year and it is below the standard convergence speed of 2 percent for regional economies (see Fischer and Stirböck 2006). The Half-distance to the steady-state is equal to 66 years in this case.

In the previous step we found the evidence of spatial dependence in the analyzed phenomenon. The presence of spatial autocorrelation can invalidate the inferential basis by OLS. It can violate one of the basic assumptions of OLS estimation – the assumption of uncorrelated errors (Fischer and Stirböck 2006). The diagnostic measure of the Moran *I* statistic is highly significant, suggesting a problem with spatial autocorrelation. Thus, we need to estimate a convergence model with spatial interactions. The results of Maximum Likelihood estimation of the spatial lagged model (6) and spatial error model (7) are displayed in the second column of Table 1.

ML estimation has given quite similar results wit *b*-parameters equal -0,087 (spatial lag model) and -0,14 (spatial error model). The *b*-parameters are also significant and have a negative sign, which is to be expected. As we see in Table 1 both LM tests of the lag and error are significant, confirming presence of spatial dependence. Relative to OLS-estiamtes, ML-estimates have achieved a higher log likelihood indicating a better quality of the models with spatial dependency.

To distinguish between spatial error and spatial lag model one can use robust LM tests. Robust measures of both error and lag model are still significant but the Robust LM (error) test has the highest value, which speaks in favor of the spatial error model. In addition higher value of pseudo-R^2 and higher log likelihood show that the overall fit of spatial error model is better.

Given the previous two clubs of regions, we have estimated the two-regimes club-convergence model.

Table 2. Estimation results of two-regimes convergence model

	Club A		Club B	
	coefficient	t-value	coefficient	t- value
a	0,86***	3,99	0,63***	3,95
b	-0,19***	-3,81	-0,14***	-3,76
conv. speed (annual)	2,11%		1,51%	
half-life	33 (years)		46 (years)	
Global tests	R^2=0,22 AIC= -1553,13			

*Significant at the level of 0,1; **Significant at the level of 0,05; ***Significant at the level of 0,01 .

Source: own calculations.

The results presented in Table 1 highly support the view of two-club convergence of health status in the European Union regions. In the case of Club A (Western Europe) the rate of convergence is above 2 %. The associated half-life is 33 years, which means that regions take 33 years for half of the initial level of life expectancy and the club specific steady-state level to disappear. The estimated convergence speed in Club B is equal about 1,5 % and it is slower than in Club A. The outcome is quite surprising because regions with higher life expectancy at the start obtain a higher speed of convergence. Broadly speaking, the process of social convergence is stronger in wealthier regions.

Studies in the field of income club-convergence indicate quite contrary conclusions (see Fischer and Stirböck 2006). According to these researchers the estimate of the convergence rate of the initially poorer regions turns out to be higher than the one of the club of initially wealthier regions.

4. Conclusions

The paper investigated health convergence for the EU regions over the period of 2002-2012. A beta-convergence process has taken place in the EU regions in the above-mentioned period. Regions with lower initial life expectancies have experienced the largest increases in life expectancies. However, the process has not been the same for all regions. Higher convergence speed is typical for more developed regions (club A) located in the south-west Europe.

From an econometric point of view, a simple single-club description by OLS method has proved to be misspecified. The level of public health (measured by life expectancy) in the EU varies spatially, with a tendency for the occurrence of spatial relationships which needed to extend cross-section data model to spatial interactions.

Adaptation of the economic growth theories to public health status has proved to be successful. Some similarities between the income distribution and life expectancy distribution across the EU regions have been confirmed. The proposed beta-convergence method can be successfully applied to the access of regional health inequalities.

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Streszczenie

NIERÓWNOŚCI ZDROWOTNE WŚRÓD REGIONÓW UNII EUROPEJSKIEJ: PODEJŚCIE BETA-KONWERGENCJI

Unia Europejska stoi obecnie przed poważnym problemem, jakim są znaczne nierówności zdrowotne między państwami członkowskimi oraz wewnątrz tych państw. Prowadzone są działania na rzecz na osiągania spójności gospodarczej i społecznej, których ważnym elementem jest wyrównywanie nierówności zdrowotnych pomiędzy regionami UE.

Niniejsza praca poświęcona jest zbadaniu nierówności zdrowotnych (mierzonych przeciętnym dalszym trwaniem życia) wśród regionów Unii Europejskiej poziomu NUTS II. W celu oceny konwergencji umieralności zaaplikowano wpracowane na gruncie teorii wzrostu gospodarczego narzędzia. Zastosowanie modelu konwergencji absolutnej pozwoli na stwierdzenie zmniejszania bądź pogłębiania się regionalnych nierówności zdrowotnych. Główna hipoteza badawcza brzmi: czy regiony o niższych początkowych wartościach długości życia doświadczyły większych wzrostów w oczekiwanej długości życia. Aby zweryfikować hipotezę o beta-konwergencji wykorzystano przestrzenne modele ekonometryczne, które ponadto pozwalają uwzględnić zależność geograficzną wśród badanych regionów. Ze względu na heterogeniczność badanych jednostek przestrzennych weryfikacji poddano także hipotezę o beta-konwergencji klubowej.

***Słowa kluczowe**: nierówności zdrowotne, konwergencja klubowa, beta-konwergencja, regiony Unii Europejskiej*

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Application Of Input-Output Analysis In The Health Care

Abstract

Usage of the economic analysis in the study of the performance of health care system does not surprise anyone nowadays. Trends that are drawn over the years fluctuate from the technology assessment of health programs – in terms of efficiency, costs or utility for patients, through methods to establishing co-payment for health services and the demand for medical services. Much of the interest is devoted to analysis of the shape of the health care system: the amount of contributions to the National Health Fund, the managing the system, both at the micro and macro level, or restructuring. Any method that allows to show dependencies, identify weaknesses/strengths of the health care system is appreciated by health policy makers.

The aim of this article is an attempt of the use of models of input-output type in the analysis of the performance of the health care sector in Poland. The construction of input-output model is based on the observed data for the specified, variously defined area – it may concern: country, region, municipality, etc., hence with the appropriate designed database, it may be possible to examine the flow of health benefits – for example, expressed in zlotys. Part of the article is dedicated to theoretical aspects of the input-output models and the problems this usage can cause.

Keywords: *input-output models, the health sector, the analysis of flows*

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1. Introduction

One of the methods most frequently used in the world in macroeconomic studies is the analysis of input-output. With the development of computerisation the range of its applications greatly expended. IO analysis, nowadays, is used in interregional research, in analyses of environmental protection, energy consumption and in, widely understood, analysis of labor intensity. Implementation of IO analysis is also caused by the ever-expanding scale of the relationship between economic regions.

Due to the multiplicity of linkages and interdependencies of business processes it is sometimes hard to clearly identify all the purposes for gathering data for IO analysis. Major objective, while collecting information, was a comparability of data. Exploration of the national economies caused creating an unified system. In the former socialist countries material balances system (System of Material Product Balances) was widely used, while other countries carried on the social accounting system (System of National Accounts or Accounting – SNA). Functioning in two different classifications prevented any comparability (See: Tomaszewicz, 1994).

The collapse of the socialist economy of Central and Eastern Europe countries and a return to a market economy resulted in changes of the objectives and needs of the data collection – these changes aimed towards the methodology of SNA.

2. Methods

2.1. Input-output tables – national level, intra relations and basic interpretations

For the founder of input-output analysis Wassily Leontief is considered (Miller, Blair, 2009, p. 2). His first application of the empirical model was based on a linear relationship between expenditures on the production of the goods and the level of production of the goods, and referred to the year 1936.

The input-output table is created with data related to specific economic areas, which may be the national economy, but also an economic region. The figures are related to a specific period in time – in practice, it is usually a year. Input output table, in general, consists of three main parts (or quarters) – see table 1. In the first quarter, the data presents the consumption of particular products (or the production of individual branches) in the production process, i.e. the cost of the raw materials, services. In terms of IO analysis, this consumption can be called the intermediate demand (production). The second quarter in IO terminology, indicates the final demand on products (or production) and non-market services. The third part of IO table characterises the value added (the Gross Domestic Product).

Table 1.Input-output table – basic symbolism

<table>
<tr><td colspan="2">Products, indirect demand</td><td>Sum of intermediate demand</td><td>Final demand</td><td>Sum of final demand</td><td>Total demand</td></tr>
<tr><td></td><td>$1 \quad 2 \quad \dots \quad j \quad \dots \quad n$</td><td></td><td>$1 \quad 2 \quad \dots \quad k \quad \dots \quad m$</td><td></td><td></td></tr>
<tr><td>1</td><td rowspan="6">$\mathbf{Z} = (Z_{ij})$
$i, j = 1, \dots, n$</td><td>Z_1</td><td rowspan="6">$\mathbf{Y} = (Y_{ik})$
$i = 1, \dots, n$
$k = 1, \dots, m$</td><td>Y_1</td><td>X_1</td></tr>
<tr><td>2</td><td>Z_2</td><td>Y_2</td><td>X_2</td></tr>
<tr><td>⋮</td><td>⋮</td><td>⋮</td><td>⋮</td></tr>
<tr><td>i</td><td>Z_i</td><td>Y_i</td><td>X_i</td></tr>
<tr><td>⋮</td><td>⋮</td><td>⋮</td><td>⋮</td></tr>
<tr><td>n</td><td>Z_n</td><td>Y_n</td><td>X_n</td></tr>
<tr><td>Σ</td><td>$K_1 \quad K_2 \quad \dots \quad K_j \quad \dots \quad K_n$</td><td></td></tr>
<tr><td>1</td><td rowspan="6">$\varsigma = (\upsilon_{lj})$
$i = 1, \dots, n$
$l = 1, .., s$</td><td>υ_1</td></tr>
<tr><td>2</td><td>υ_2</td></tr>
<tr><td>⋮</td><td>⋮</td></tr>
<tr><td>l</td><td>υ_l</td></tr>
<tr><td>⋮</td><td>⋮</td></tr>
<tr><td>s</td><td>υ_s</td></tr>
<tr><td></td><td>$V_1 \quad V_2 \quad \dots \quad V_j \quad \dots \quad V_n$</td></tr>
<tr><td></td><td>$X_1 \quad X_2 \quad \dots \quad X_j \quad \dots \quad X_n$</td></tr>
</table>

Legend: z_{ij} – flow from i to j sector of a homogenous product, **Z** – matrix of flows in n sectors, and m kinds of final demand, and s elements of value added; X_i – final demand of i sector; Y_i – final demand for production od i sector and **Y** – vector of expenditures of final receivers of each branch; υ_{lj} – elements of value added (for l=1, …, s), ς – matrix of value added; **V** – value added vector of each sector. Rows indicate the total output of each product is used for consumption by the various industries, and final demand purposes. Columns provide information on the input composition of the total supply of each product – this is comprised by the national production.

Source: Miller, Blair, 2009, pp. 3, 13, 47; Tomaszewicz, 1994, p. 56.

Problems of construction of the IO occur within classification, definitions, units of measurement and data arrangement. The formal properties of the data array results from the adopted system of national accounts. However, specific IO tables ultimately depend on the purposes of their construction, and typically, they are limited with the possibilities of obtaining the necessary data.

The fundamental data necessary for the IO analysis is located in the first quarter of the input-output matrix. If transactions take place between sectors of productive activity, the matrix is called the matrix of interindustry flows. In this section, manufacturing sectors (branches, groups of branches) are also presented as activities wearing products (manufactures) of other sectors.

In general, the data flow between distinguished products manufacturing sectors may be presented in physical units – this causes measurement problems, which in general are greater, then when the flows are expressed in monetary terms. However, the monetary units are also not universal, as the prices of goods are changing and make it difficult to analyse the level of inputs in physical units and can distort the image of significant changes in technology and the structure of outputs.

The second quarter of the IO does not concern production – it indicates the final demand. Generally, the final demand includes private consumption (the households), consumption expenditure (the government), net export (the foreign customers), capital expenditures (the investors) and demand for the product associated with the change in inventory levels. The basic theory of IO assumes that the final demand is exogenous in relation to the manufacturing sectors, i.e. does not depend on the level of production in these sectors. The final demand equals the sum of demands (expenditures) of all final receivers (k=1, … , m) for i sector's production $Y_i = \sum_{k=1}^{m} y_{ik}$.

For each of n sectors it is possible to construct equations for production used on productive purposes (Miller, Blair, 2009, p. 19):

$$\begin{aligned} X_1 &= z_{11} + z_{12} + ... + z_{1n} + Y_1, \\ X_2 &= z_{21} + z_{22} + ... + z_{2n} + Y_2, \\ &\vdots \\ X_n &= z_{n1} + z_{n2} + ... + z_{nn} + Y_n. \end{aligned} \tag{1}$$

In the similar sense, it is possible to construct equations expressing the inputs in each j sector:

$$\begin{aligned} X_1 &= z_{11} + z_{12} + ... + z_{1n} + V_1, \\ X_2 &= z_{21} + z_{22} + ... + z_{2n} + V_2, \\ &\vdots \\ X_n &= z_{n1} + z_{n2} + ... + z_{nn} + V_n. \end{aligned} \tag{2}$$

The first equation system indicates the total consumption of the production of each sector, i.e. the total demand of production and final recipients for the production of each sector, and the second system – the inputs on the production of these sectors, i.e. the value of global production of each sector. Because the value of the total consumption of the outputs of the sector must be equal to the value of outputs produced (assuming that there is no import), the X_i=X_j when i=j.

The fundamental assumption in IO analysis is that the flow of products from *i* to *j* sector depends on the level of global production of *j* sector. Significantly, the higher level of car production, the higher demand of different products: steel, coal, leather or textiles. On the basis of IO analysis it is possible to compare the inputs and global value to calculate the technical or direct input ratios: $a_{ij} = z_{ij} / X_j$. Further it is possible to establish the matrix of the IO ratios: $\mathbf{A}_{nxn} = [a_{ij}]$, and using this coefficients, it is possible to express the total production of each sector:

$$\mathbf{X} = \mathbf{AX} + \mathbf{Y}. \quad (3)$$

2.2. Regional and multiregional IO models

In literature, there are at least two main factors that distinguish the modelling issues at regional level from IO models for the entire national economy. Firstly, the structure of expenditures on production in the region could be significantly different from the structure described by the matrix **A** coefficients for the whole country. Secondly, if the considered region is smaller, the more economically dependent from its surrounding it becomes.

There are many reasons for IO analysis at the regional level (Miller, Blair, 2009, pp. 70-75). These models should primarily provide assistance in determining the impact of the additional final demand both for products manufactured in the region, as well as for traded into the region raw materials and other products.

The main problem arising in connection with the analysis of input-output at the regional level is the construction of an array of coefficients of direct regional expenditures. Such estimates are rarely constructed on the basis of surveys, and most often generated on the basis of technical coefficients for the whole country. Although, this solution is more frequently used, it is problematic to transform direct input ratios of the structure on national level to the regional scheme, due to, for instance, larger variety of products manufactured at the macro level.

Following the nomenclature of classic IO models, when establishing the total demand on products of *i* sector, it is possible to calculate the regional technical ratios, as follows: $a_{ij}^R = x_{ij}^R / X_j^R$, where $x_{ij}^R = x_{ij}^{RR} + x_{ij}^{ZR}$ is the products consumption in *i* sector needed in production of *j* sector of *R* region, consisting of products made in (x_{ij}^{RR}) and outside (x_{ij}^{ZR}) the region (Miller, Blair, 2009, pp. 76-80). When having the $\mathbf{A}^R$ matrix of regional direct input ratios it is possible to estimate the influence of final demand of *R* region on the global production of sectors on national level: $\bar{\mathbf{X}}^R = (\mathbf{I} - \mathbf{A}^R)^{-1}\mathbf{Y}^R$.

Regional IO models may relate to a single, two or more regions in mutual relationships. In order to illustrate the simultaneously multiregional connections it is possible to assume the structure, as follows:

$$\aleph = \left[\begin{array}{c|c} \mathbf{X^{RR}} & \mathbf{X^{RZ}} \\ \hline \mathbf{X^{ZR}} & \mathbf{X^{ZZ}} \end{array}\right], \tag{4}$$

where: $\mathbf{X^{RR}}$ indicates the flow in R region, $\mathbf{X^{RZ}}$ indicates the flow from R to Z region, $\mathbf{X^{ZR}}$ indicates the flow from Z to R region, and $\mathbf{X^{ZZ}}$ indicates the flow outside R region.

When considering the regional economy of two regions and 2 sectors, the global production can be defined as:

$$X_i^R = x_{i1}^{RR} + x_{i2}^{RR} + x_{i1}^{ZR} + x_{i2}^{ZR} + Y_i^R . \tag{5}$$

Further, it is possible to define the interregional IO model:

$$\left\{\left[\begin{array}{c|c} \mathbf{I} & \mathbf{0} \\ \hline \mathbf{0} & \mathbf{I} \end{array}\right] - \left[\begin{array}{c|c} \mathbf{A^{RR}} & \mathbf{A^{RZ}} \\ \hline \mathbf{A^{ZR}} & \mathbf{A^{ZZ}} \end{array}\right]\right\}\left[\begin{array}{c} \mathbf{X^{R}} \\ \hline \mathbf{X^{Z}} \end{array}\right] = \left[\begin{array}{c} \mathbf{Y^{R}} \\ \hline \mathbf{Y^{Z}} \end{array}\right], \tag{6}$$

where: $\mathbf{A^{RZ}}$ and $\mathbf{A^{ZR}}$ indicate the transactional ratios.

2.3. Possible applications of IO in the health sector - National Health Accounts (NHA)

Health and health policy recently became transnational, global dimension, because of the role and the functions of solving health problems common to the population. In the modern system, the dilemma connected with the optimal allocation of limited resources is one of the fundamental problems in decision making involving the health policy.

Implementation of the System of Health Accounts (SHA) has been launched by the OECD Member States in order to support proper organization and analysis of health data. This implementation increased the transparency interrelated methods of performance and financing services for individual goods in health, providing services, through a comprehensive and coherent synthesis of health-related transactions. Assessment of the level of expenditure on health in one country allows comparing the size of this expenditure with other countries and is often used to draw conclusions about the effectiveness of functioning of the health system.

The problems in system construction result from the specifics of the health sector. These obstacles are connected with the measurement methods, data collection and the interpretation of results. National systems aim at creating common, country-specific classification methods of health funding, which allowed making international comparisons of these values, estimating trends and indicating factors affecting these value.

System of Health Accounts provides a common structure for health expenditures and methods of financing. SHA answers three key questions:

- where did the funding come from,
- where are the funds directed,
- what kind of services are performed and what type of goods are delivered.

SHA is organized around a triaxial ranking system of health expenditures, settled in the International Classification for Health Accounts (ICHA) and divided into 3 categories:

- sources of funding (ICHA-HF),
- providers of health services (ICHA-HP);
- functions of health care (ICHA-HC).

An example of the SHA table is presented in table 2 below.

Table 2. System of Health Accounts (SHA) in Poland – ex. Functional Classification of Health Care

Functional Classification of Health Care	Total expenditures	General government except social security funds	Social security funds	Private social insurance	Private household out-of-pocket expenditure	Non-profit institutions serving households	Corporations (other than health insurance)	Rest of the world
Services of curative care	20 503 966.50	840 272.20	15 961 347.60	172 500.00	3 529 846.70	-	-	-
Services of rehabilitative care	694 356.10	13 850.50	481 053.10	-	199 452.50	-	-	-
Services of long-term nursing care	2 464 915.30	1 268 939.60	1 177 422.00	-	18 553.70	-	-	-
Ancillary services to health care	1 251 111.10	48 364.30	844 125.90	6 100.00	352 520.90	-	-	-
Medical goods dispensed to out-patients	10 796 588.60	7 339.10	3 700 279.20	-	6 920 540.50	168 429.80	-	-
Non-classified services	912 636.90	56 181.50	507 691.50	-	-	148 763.80	200 000.00	-
Prevention and public health services	1 496 839.10	1 269 785.40	20 349.00	-	-	-	205 415.40	1 289.30
Health administration and health insurance	1 711 477.40	592 681.40	1 114 552.40	4 200.00	-	-	-	43.6
Total current expenditures	39 831 891.00	4 097 414.10	23 806 820.80	182 800.00	11 020 914.30	317 193.60	405 415.40	1 332.90
Health-related functions	35 039 077.70	2 665 661.80	32 236 900.00	-	-	1 820.90	116 983.40	17 711.60
of which investments in health	1 534 444.80	1 522 979.90	-	-	-	-	-	11 464.90
Education and training of health personnel	854.1	-	-	-	-	-	-	854.1
Research and development in health	489 272.10	365 106.90	-	-	-	1 820.90	116 983.40	5 360.90
Food, hygiene and drinking water control	11.9	-	-	-	-	-	-	11.9
Environmental health	19.8	-	-	-	-	-	-	19.8
Administration and provision of social services in kind to assist living with disease and impairment	-	-	-	-	-	-	-	-
Administration and provision of health related cash-benefits	33 014 475.00	777 575.00	32 236 900.00	-	-	-	-	-

Source: Schneider M. (ed.), 2001, A System of Health Accounts in Poland, Warsaw, p. 132.

2.4. Some problems on construction of IO tables in health care

Although there are similarities in construction of the System of National Accounts and the System of Health Accounts tables, it is almost impossible to construct a proper IO table for the purpose of the flow analysis.

The biggest problem regards to the triaxial ranking system and the specification of the system itself. The classification effectively denies the possibility of the flow arrangement, while, when looking on the functional classification, the aggregation of the health expenditures is running differently, then when aggregating data on basis of source of funding. In short, it is not possible to distinguish what amount of expenditures in services of curative care is used by the ancillary services to health care.

When considering the regional IO analysis, it is possible to indicate the categories of expenditures on voivodships level. This division however, does not relieve the condition of flows (for instance between regions) arrangement. What's more, when talking about health system management, one is aware that the funding system is independent on regional level. The amounts of funds directly depend on the National Health Fund (the macro level).

Problem, when conducting IO analysis in health care arises also with the category of final demand – demand for specific products. Transformation of the demand into the manufacturing process may indicate the demand for the level of production of specific products or production of sector that manufactures these products as primary. This leads to a consequence on the shape of the IO table: product to product, sector to sector, or mixed table: product on sector. Generally, it is impossible to construct an IO matrix, which would be an ideal base for all kinds of testing. In addition, the problem of transition from one system to another would not exist if the system was not producing secondary products. This problem could be easily solved when the information on the structure of manufacturing cost is available – such data are not generally available.

2.5. Acquiring the IO of health care sector

The use of models based on the production function allows only the assessment of factors that determine the functioning of the health care system that are significant from a statistical point of view, without indicating units operating in the health system that are ineffective. In the analyses of the productivity not only quantitative information associated with e.g. given number of medical benefits should be considered, but also information reflecting the level of quality of health services and the expected effects of health system functioning. Then, it is possible, firstly, to identify and secondly to point out, which combinations of the inputs are most effective. Choosing the most effective combination between inputs and outputs is the essence of the process of resources allocation (Jewczak, Żółtaszek 2011b, p. 195).

Efficiency research is today regarded as the key element of decision-making, in order to maximize achieved outputs. The concept of the effectiveness is commonly identified with its economic nature and focuses mainly on two aspects (Suchecka 2009, p. 119):

- the technology – an efficient enterprise maximises its production at the given inputs;
- the costs – an efficient company reaches target level of production, while minimising costs.

Achieving efficiency in the economic sense is related to the existence of technical efficiency. In health economics, technical efficiency is defined as the result of hospital service activities relating to the provision of services at a certain time and expenditures (Suchecka 2009, p. 120). Therefore, evaluation of the effectiveness involves determining an appropriate combination of the factors allowing the maximisation of the outputs level.

In measuring the technical efficiency of health care entities, most often, nonparametric methods are used – this approach allows analysing incurred costs and achieved benefits (Vincov 2005).

Data Envelopment Analysis (DEA) is a nonparametric method of acquiring efficiency that compares units with top counterparts. Nonparametric methods also do not require any *a priori* assumptions towards the function form of the relationship between the variables – evaluation is made only on the basis of the available data. Further, DEA method is based on linear programming methodology for determining the relative efficiency of a set of decision-making units (DMUs). DEA determines the efficiency of each DMU in relation to estimated, possible for all DMUs, production limit. DEA focused on the best results and individual DMU, not on measures of average values. As a result, it is possible to obtain a specific change in inputs and outputs for leading to optimality (in Pareto sense).

The literature identifies two main types of DEA models:

- with fixed effects of scale (constant returns-of-scale – CRS),
- with variable effects scale (variable return-of-scale – VRS).

Both approach results indicates the same set of effective DMUs.

Depending on the model CRS/VRS different information is obtained. Using the CRS model an index of total value of technical efficiency is received. Using the VRS approach, the indicator will present the level of pure technical efficiency (Jewczak, Żółtaszek 2011b, p. 197).

DEA models can be differently oriented: on inputs or outputs. In the first case, the method defines the efficiency frontier by estimating, for each DMU, the maximum possible reduction in the level of expenditures, while maintaining the same level of the results. In the case of the second variant, DEA seeks the maximum, proportional increase in production levels of the outputs, while maintaining the same level of the inputs. The analysis results allow determining the effectiveness of individual DMU in 0-1 interval (Suchecka 2009, pp. 129-130) – DMU reaching a score of 1 is relatively the most effective. When scoring less than 1, DMU should be described as relatively inefficient.

3. Some results on inputs/outputs

3.1. Basic IO analysis in health care

Let us assume that table 3 presents the hypothetical 3-sectoral health care system, in which patients are given 3 types of services: curative care, rehabilitative care and long-term nursing care. Services are interpreted in monetary terms in thousands of zlotys. For each service, information on final and total demand, value added, and global value is known. Following the order of IO analysis, matrix of direct input ratios (**A**) has been estimated, of which results are also presented in table below (table 3 also presents the indirect input ratios).

As results of input-output ratios show, the sums of columns of services equal: 0.50 for HC.1, 0.76 for HC.2 and 0.68 for HC.3. In each case, the costs of resources of services from other categories, is only a part of costs of production unit of a category. Using the IO ratios in the analysis, it is easy to predict the future value of inputs, when, for instance, the production of first category increases tenfold.

Table 3. Hypothetical IO system – simplification

	Intermediate demand			Final demand (Y_i)	Total demand (X_i)
	Services of curative care (HC.1)	Services of rehabilitative care (HC.2)	Services of long-term nursing care (HC.3)		
Services	366.00	713.70	823.50	1939.80	4392.00
	1098.00	210.45	1427.40	658.80	2287.50
	732.00	823.50	219.60	1610.40	3623.40
Value added (V_j)	2196.00	539.85	1152.90	3888.75	
Global value (X_j)	4392.00	2287.50	3623.40		10302.90
A	0.08	0.31	0.23		
	0.25	0.09	0.39		
	0.17	0.36	0.06		
Indirect input ratios	0.50	0.24	0.32		

Note: values for services, demand, value added and global value expressed in thousands zlotys.

Source: developed by Authors.

Table 4. Changes in inputs and production

IO ratios	New level of production	New level of inputs
0.08	43920.00	3660.00
0.25		10980.00
0.17		7320.00

Source: developed by Authors.

3.2. Productivity assessment

Any analysis on the condition of health care systems usually begins with the description of changes that occurred in recent years. Table 5 below shows the chain indices calculated for years 2008-2012, and the annual average percentage change in the levels of expenditures.

Table 5. Changes in health care expenditure levels in Poland by their function

Health care expenditure by function	2009/ 2008	2010/ 2009	2011/ 2010	2012/ 2011	Annual average % change
Services of curative care (HC.1)	1.11	1.02	1.04	1.11	6.74%
Services of rehabilitative care (HC.2)	1.14	1.13	1.02	1.15	10.61%
Services of long-term nursing care (HC.3)	1.08	1.15	1.08	1.04	8.57%
Ancillary services to health care (HC.4)	1.18	1.01	1.08	1.10	9.11%
Medical goods dispensed to out-patients (HC.5)	1.09	1.01	1.04	1.05	4.56%
Prevention and public health services (HC.6)	1.08	0.94	1.04	1.08	3.37%
Health administration and health insurance (HC.7)	0.94	0.97	1.27	0.99	3.37%
Investments in health (HC.R.1)	1.12	1.02	1.08	1.13	8.71%
Education and training of health personnel (HC.R.2)	1.14	1.04	1.03	1.08	7.01%
Research and development in health (HC.R.3)	1.34	1.12	1.22	0.95	14.74%
Food. hygiene and drinking water control (HC.R.4)	1.01	0.98	1.06	1.30	8.29%
Administration and provision of social services in kind to assist living with disease and impairment (HC.R.6)	1.07	1.03	0.97	1.11	4.52%
Administration and provision of health related cash-benefits (HC.R.7)	1.10	1.04	1.02	0.92	1.53%

Source: developed by Authors on the basis of EUROSTAT statistical data.

Considering some fluctuations in the values of indices, average annual percentage change shows that the level of expenditures (by its function) increased in time. The highest average annual expenditures change was observed in the field of research and development in health (HC.R.3) – 14.74%, the lowest in administration (HC.R.7) – 1.53%.

In the research on productivity inputs and outputs were categorized as follows:

1. the inputs consisted of:
   a. number of beds,
   b. number of doctors,
   c. number of nurses.

2. the outputs consisted of:
   a. number of patients treated during the year,
   b. man-days of treatment.

On the basis of the variables listed above, the productivity levels were assessed – in this research an input-orientated CSR approach was used. Initial results for the changes in inputs, outputs and productivity levels were presented in table 6. Looking at the annual average percentage change it could be observed that the inputs grew since the 2008 – on average annual increase was 3.06%. While the inputs continued to increase in the analysed period, the outputs and the productivity on average decreased – outputs were decreasing annually by 0.17% and the productivity of health care sector by 0.62% (assuming the unidirectional change rate).

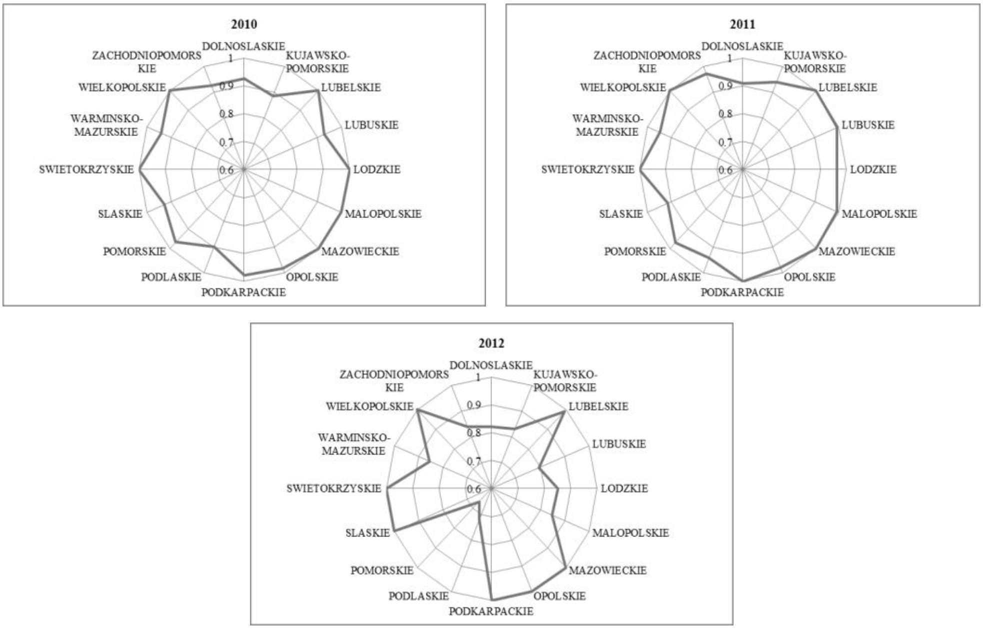
Table 6. Single base indices (2008=100), changes in inputs, outputs and productivity levels of health care in Poland, and annual average % change

Specification	2008	2009	2010	2011	2012	Annual average % change
inputs	1.00	1.02	1.05	1.09	1.13	3.06%
outputs	1.00	1.00	0.97	0.98	0.99	-0.17%
productivity	1.00	1.06	1.05	1.07	0.98	-0.62%

Source: developed by Authors on the basis of EUROSTAT statistical data.

Looking more detailed at the productivity, during the research it was possible to calculate the productivity of health entities at the regional level (fig. 1). The most diverse year, as the productivity is concerned, was the 2008 and 2012, the less varied was the 2011. The figure 1 below indicates also the changes in regions' productivity changes in time – regions with constant, effective productivity were: Mazowieckie and Wielkopolskie.

Figure 1. Productivity levels of health entities in 2008-2012

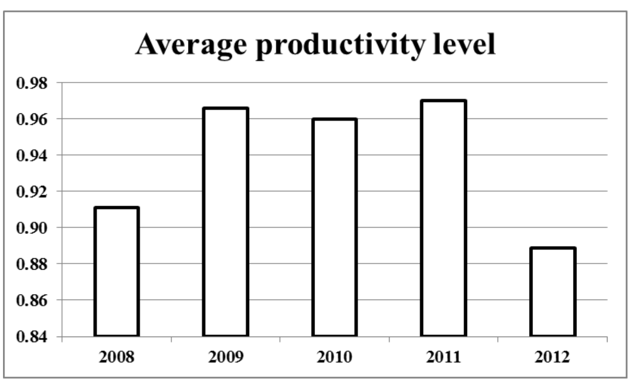


Legend: value 1 indicates the most effective region; any values below this level indicate the ineffective region.

Source: developed by Authors on the basis of EUROSTAT statistical data.

Summing up the research on the inputs/outputs an their relation in the health care sector, figure 2 indicates the total, average annual productivity. Although it was possible to mention regions with effective productivity, in Poland, from 2008 to 2012 the health care system was ineffective. As it was stated earlier the less productivity diverse period was 2011, and the figure below indicated that this was the best year, on average.

Figure 2. Productivity levels of health entities in 2008-2012



Source: developed by Authors on the basis of EUROSTAT statistical data.

4. Conclusions and discussion

Research indicated that it is possible to run an input/output analysis in health care; however it is not possible to conduct the research in the sense of classical IO analysis. This IO analysis concerns only the research on productivity and effectiveness of the health care. The major problem with the analysis derives from the database construction. Both at the macro and regional levels, there are no information on flows of health products or monetary values for products, flows that would allow conducting a typical input and output analysis.

Many authors (e.g. Sargento, 2009), especially on regional level, discuss on some methods that could be possible to use in data disaggregation. Firstly, following Isard and Bramhall [1960], it is possible to estimate a gravity model to identify the flow:

$$x^{rs} = G\frac{(P^r)(P^s)}{(\delta^{rs})^{\alpha}}, \tag{7}$$

where: x^{rs} – indicates the export from origin r to destination s, G represents the constant of proportionality and P^r and P^s express the r and s population, δ^{rs} shows the spatial distance between the origin and destination of the flow and the α enhance the flexibility of the of the gravity model (this parameter should be estimated). Research also point out the need of testing in the analysis for the spatial dependence. Gravity model assumes that locations are completely independent – the assumption, which according to the first Tobler's law is false. The exploration moved towards spatial models (e.g. Spatial Autoregressive Model or Spatial Error Model). Both approaches allow incorporating a spatial weights matrix **W**, which could indicate for the spatial dependency (see: Suchecki, 2010, pp. 238-251). Using spatial modelling enables to establish the influence in the flow resulting from the neighbouring scheme (described by the **W** matrix) of different regions.

In estimating the regional flows some researchers use the location quotients (*LQ*) (see: Jewczak, Żółtaszek 2011a, p. 90). Within this approach, the possible flow of services constructions results from the measure properties. While comparing the regional to national structure of production, it is possible on the basis of *LQ* values to establish, when a region is self-sufficient and could even export the production to his neighbours, or needs to import goods and services.

Major final remark that discourages from using the IO analysis in the health care sector derives from the health sector itself: the inputs in *i* field/service category is not an output in *j*'s.

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Streszczenie

ZASTOSOWANIE ANALIZ INPUT-OUTPUT W SEKTORZE OPIEKI ZDROWOTNEJ

Wspieranie się analizami ekonomicznymi w badaniach stanu systemu opieki zdrowotnej, dziś już nie dziwi nikogo. Trendy, jakie rysują się na przestrzeni lat fluktuują przez techniki oceny programów zdrowotnych – pod kątem ich efektywności, kosztów lub użyteczności świadczeń dla pacjentów, poprzez metody oceny skłonności do współpłacenia

za świadczenia zdrowotne oraz zapotrzebowania na świadczenia medyczne. Wiele miejsca poświęca się analizom kształtu systemu opieki zdrowotnej: wysokości składki na Narodowy Fundusz Zdrowia, zmianie sposobów zarządzania systemem, zarówno na szczeblu mikro, jak i makro, czy procesom restrukturyzacyjnym. Każda metoda, która pozwala wykazać zależności, wskazać słabe/mocne punkty systemu opieki zdrowotnej jest mile widziana przez twórców polityki zdrowotnej.

Celem artykułu jest próba zastosowanie modeli typu input-output w analizach stanu sektora opieki zdrowotnej w Polsce. Budowa takich modeli input-output bazuje na danych obserwowanych dla wyszczególnionego, różnie definiowanego obszaru – może dotyczyć, kraju, regionu, gminy, itp., stąd przy odpowiedniej konstrukcji bazy danych możliwe jest zbadanie przepływów świadczeń zdrowotnych w kategoriach finansowych – na przykład wyrażonych w złotych. Część artykułu zostanie poświęcona rozważaniom teoretycznym nad modelami wykorzystania modeli input-output oraz problemów, które ich wykorzystanie może przysporzyć.

Słowa kluczowe*: modele input-output, sektor opieki zdrowotnej, analiza przepływów*

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Impact Of The Manufacturing Sector On The Export Competitiveness Of European Countries – A Spatial Panel Analysis

Abstract

The purpose of this paper is to determine how changes in the export competitiveness of the EU economy (measured by exports and net exports) depend on changes in the competitiveness of processing industries, on the basis of manufacturing data from 19 EU countries over years 1995-2009 and using a spatial panel data model. The determinants of export competitiveness are selected in the light of predictions from international trade theory, growth theory and the theory of innovation. In particular, the paper explores how the size of foreign demand, the value of domestic demand, the level of ULC in the sector, the degree of openness of the sector to foreign markets, labour productivity and intermediate consumption in a sector affect the export competitiveness of the European economies selected. The results from spatial data models lead to a conclusion about the statistical significance of spatial dependencies in export competitiveness modelling. The analysis indicates the different determinants of export competitiveness, both if it is measured by export value and if it measured by net exports. The authors hope that the results will be a voice in the discussion on enhancing the competitiveness of European industrial sectors.

***Keywords**: international trade, export competitiveness, manufacturing, spatial data model, European Union*

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1. Introduction

In 2010, the European Union announced a new 'Europe 2020 Strategy' with three key drivers for the next decade: smart growth (fostering knowledge, innovation, education and a digital society), sustainable growth (making production more resource-efficient while boosting competitiveness) and inclusive growth (increasing participation in the labour market, the acquisition of skills and the fight against poverty). Although the Strategy sets five targets, which define where the EU should be by 2020, each EU country is trying to find a way to achieve these objectives. One of the possible strategies is an export growth strategy, based mainly on the export of manufacturing.

The positive experiences of Asian countries in the 90s, which achieved sustained economic growth through a strong export orientation of their economies could be a sufficient stimulus. However, nowadays in the literature there is a discussion of whether an export competitiveness oriented policy is still feasible (Ketels 2010, p.4). Some empirical analyses provide insights into a positive and stable relationship between trade and growth (Baldwin 2003, p. 502; Dollar, Kray 2002, p.138) or between trade and productivity (Coe, Helpman 1995, p. 962; Ciccone, Alcala 2004, p.623). Other economists are more sceptical, especially regarding the stability of this relationship over time (Rodriquez, Rodik 2000, p. 262; Clemens, Wiliamson 2001, p. 44). Nevertheless, there is no consensus in the discussion about the usefulness of an export grow strategy, and export competitiveness is still one of the most popular tools for the assessment of country competitiveness and still the central element in the competitiveness policies of many countries.

On the basis of the numerous reports we can conclude that the most competitive countries are often the most industrialized, providing leadership in technology and innovation. Reffering to UNIDO's Industrial Development Report 2012-2013 and Global Competitiveness Report 2013-2013, we can confirm that the most competitive economies in the world – such as Switzerland, Singapore, Germany, the USA and Japan – simultaneously belong to the group of the top ten most industrially competitive nations. Furthermore, most EU countries reach a better position among the most industrialized countries in the world than their ranking in the Global Competitiveness Report.[1] According to these reports, for example, the Polish economy is ranked in 41st place among 144 competitive economies (measured by the Global Competitiveness Index) but

[1] For more about GCI, see: www. http://reports.weforum.org/global-competitiveness-report-2012-2013/; to find out more about CIP, see: http://www.unido.org/fileadmin/user_media/Services/PSD/Competitive_Industrial_Performance_Report_UNIDO_2012_2013.PDF

in 25th place in the ranking of 133 industrialized countries measured by CPI (Competitive Industrial Performance). Therefore, the industrial potential of the Polish economy is much greater than its global competitiveness level. The strength of Polish industry lies mainly in a large share of value added manufacturing in total GDP (22.5% in 2013) and of manufactured exports in total exports (87.83% in 2013), which justifies the choice of a strong manufacturing export oriented strategy in the Polish economy.

To assess whether it is worth focusing on an industrial goods export growth strategy, an evaluation of how manufacturing exports determine the competitiveness of EU economies is needed. The purpose of this article is to determine how changes in the competitiveness of the economy (measured either as total exports or net exports) depend on changes in the competitiveness of industry, using manufacturing data for selected 19 EU countries in years 1995-2009 and a spatial panel data model. Hypotheses about the spatial relationships between the net export/export value of selected countries will also be verified. The paper is organized as follows. The next section contains discussion of different approaches to defining and measuring export competitiveness. In section 3, the determinants of export competitiveness are discussed. Section 4 opens up the methodological part of the paper by introducing the methodology of spatial panel data models. Section 5 presents the data and the results of the analysis, and the last section gives our conclusions.

2. Export competitiveness as a narrow definition of macro-competitiveness - theoretical issues

Over the last three decades, the term competitiveness has been widely used and sometimes abused. Despite this, the concept of competitiveness is still not clearly defined. Even Porter, in his book "The competitiveness advantage of nations" (Porter 1990) does not directly define competitiveness, even though he uses the term repeatedly.

The main difficulties in defining competitiveness are met at the macro level. Krugman call these attempts a "dangerous obsession" because, unlike firms, nations cannot be uncompetitive, i.e. the line between a competitive economy and a non-competitive one does not exist (Krugman 1981, p.960). Despite the lack of consensus among economists on how to define international competitiveness at the macro level, there is a consensus in the literature that the origin of the concept of international competitiveness should be found in mainstream theories of international trade. In this strand of literature, national competitiveness is understood narrowly as " the degree to which [a nation] can, under free and fair market conditions, produce goods and services that meet the test of international markets" (President's Commission on Competitiveness 1984, p.1). Thus, the more products and services a country can sell abroad, the more competitive it is. Nowadays, definitions of macro competitiveness are much broader. Good results in international trade are simultaneously connected with the achievement of a high standard of living for citizens (European Commission 2000, p.17), high real domestic incomes (OECD 1992, p.11), productivity (Word Economic Forum 2012, p.3), or simply better prosperity for people.

Therefore, a variety of country competitiveness definitions result from the different aspects of the economy to which these definitions refer. In this paper, we do not assess all aspects of competitiveness but focus mainly on export competitiveness. Export competitiveness, which is often defined as "the ability of the country to produce and sell goods and services in foreign markets at prices and quality that ensure long-term viability and sustainability", can be treated as a synonym of the above-mentioned narrow definition of national competitiveness. This is because the value of a country's exports is generally used as the most important diagnostic tool to measure the condition of an economy's fundamentals and the best way to assess the capabilities of national companies to compete in international markets (Farole 2010, p.5).

The use of the value of exports as an index of export competeviness has sometimes been criticized. It has been held that analysis based on this figure could lead to inconsistent or even contradictory findings, due to the many possible economic phenomena which affect the value of exports (Carneiro, Rocha, Silva, 2007, p.3). An alternative approach is to use net exports (instead of total exports) as a measure of export competitiveness (Deardorff 1980, pp. 941-957, Greehalgh,Taylord 1990, pp.12-15, Greennhalg, Taylord, Wilson 1994, pp.102-135). The use of this measure is particularly appropriate in view of the serious external imbalances from which many EU countries still suffer. If we take net exports as our indicator of export competitiveness, we understand export competitiveness as "the ability of the economy to cope with international competition and maintain a high rate of domestic demand without compromising the trade balance" (Wysokińska 2001, p.36). In this paper we analyze export competitiveness using both indicators of export competitiveness, i.e. the values of both, total exports and net exports.

There are various papers exploring the relationship between export competitiveness, measured by export value, and its determinants. Very often these studies consider only one particular European economy, not the EU countries as a single group. Moreover, few analyses related to the export competitiveness of EU countries focus on evaluating the influence of one particular factor on the export value of the European Union (e.g. labour costs, productivity, innovation, or relative prices). There are no papers examining the impact of all these determinants on the export competitiveness of the EU countries within a single study. Furthermore, the role of spatial relations in export competitiveness is always ignored. The present paper, therefore, fills this gap.

It is even harder to find analyses of EU export competitiveness measured in terms of net exports. In the literature we find the view that competitiveness and trade deficits are two different things (Lenz 1991, pp.89-95) and that the cause of trade deficits is connected to other macroeconomic fundamentals than the level of an economy's competitiveness (Hilke, Nelson 1987, p.152; Parry 1994, pp.20-23). The present study checks the hypothesis of a significant impact of industrial competitiveness on the trade balance in the EU countries.

3. The main determinants of export competitiveness and spatial relations in export competitiveness research

In the literature we can find a few dominant trends identifying the determinants of export competitiveness of economies. First of all, analyses based on classical and neoclassical foreign trade theories focus on the price or non-price competitiveness of the economy, determined by decreases in the real exchange rate (Boltho 1996, p.3), by lower unit labour costs, or by low relative values of export prices (Aiginger 2009, p.35).

The second trend in research is connected with Schumpeter's findings and concentrates on R&D intensity and its impact on the international competitiveness of the economy (Lall, Kumar 1981, p.453-463; Hirsch, Bijaoui 1985, p.247; Wakelin 1998, p.840). In addition, analyses relating to the new theories of international trade and growth based on a model of imperfect competition (Grossman, Helpman 1991) focus on studying the relationship between the intensity of innovation among sectors and the level of international competitiveness of the economy (Amendola et al 1993, pp.451-471, Amendola, Padoan, Guerrieri 1992, pp.173-197; Soete 1981, pp.638-660; Fragerberg 1988, pp.355-374).

The third line of research is related to the 'learning by exporting' mechanism, where export activity influences the efficiency level of firms in the domestic market and their productivity, and thereby affects the growth of international competitiveness of the economy (Wagner 2007, p.67).

Other studies indicate other determinants of international competitiveness which do not fit the above-mentioned trends, such as: degree of concentration, degree of product differentiation, degree of openness, or the intensity of intra-industry trade (Helpman, Krugman 1985, pp.16-29).

In order to meet the aims of this study, here we focus on six determinants that affect competitiveness, some at the macro level (exports) and some at the mezzo level (industry sector). The choice of determinants is to a certain extent conditioned by the availability of statistical data.

The basic determinant of export competitiveness are prices. The most commonly used measures of price competitiveness are the real effective exchange rate and price indices such as the CPI, PPI and relative unit prices. In addition to the assessment of price competitiveness, a cost approach is used, assuming that the price level is determined mainly by the level of the production costs involved, mainly labour costs. Within this approach, the best measure is unit labour costs (Peters 2010, p.10) and this will be adopted as one of the determinants employed in this paper. We hypothesize that a decrease in unit labour costs will promote export competitiveness.

The second determinant of export competitiveness chosen here is foreign demand. The vast majority of EU country exports are directed at other EU markets. The EU market is highly integrated, barrier-free and contains trade partners with a relatively similar demand structure. Therefore, the greater the demand from foreign partners, the greater the value of exports a country might expect to achieve (Ghose, Kharasa 1993, pp.377-398).

The third factor which could influence the value of total or net exports is domestic demand. One might hypothesize that a high level of domestic demand does not lead to improving the competitiveness of exports, i.e. a significant increase in domestic demand for a sector’s products may discourage domestic manufacturers from increasing sales abroad. On the other hand, exporters who often incur high costs of entering a foreign market will probably increase their exports even in the case of domestic demand growth. Porter also holds the view that a growth in domestic demand positively affects export competitiveness, i.e. the bigger demand from national buyers, the faster businesses update and modernize their offer, and the more exports can be expected (Porter 1990).

Another factor which positively influences export competitiveness is openness of the economy. It is likely that openness of the market causes a greater accumulation of production factors and a better transfer of production factors to more productive sectors, which creates the possibility of achieving comparative advantages. In addition, openness allows economies of scale and the benefits from agglomeration to be achieved in production, which can accelerate the transfer of technology (Nair, Madhavan, Vengedasalam 2006, pp. 878-890).

A further determinant of export competitiveness chosen in this study is labour productivity. Growth in labour productivity positively translates into an increase in export competitiveness through two channels. We call the first of these the technological effect. This is reflected in an increasing number of new products or new markets. The second channel of transfer of labour productivity growth to export competitiveness is visible in competitive pricing, i.e. low unit labour costs for domestic producers (Ciccone, Alcala 2004, pp.613-646).

We also use intra-industry indices to explain changes in the export competitiveness of selected EU countries. Intra-industry trade refers to the exchange of similar products belonging to the same industry, i.e. the same types of goods are both imported and exported. Countries with similar relative amounts of factors of production are predicted to have intra-industry trade and they gain from this due to economies of scale (lower costs) and more consumer choice (Krugman 1981, pp.959-973).

Next, we choose investment intensity as a determinant of export competitiveness in our analysis. This indicator is calculated as the ratio of gross fixed capital formation in a certain industry to the value added in that industry and shows how much of the new value added in the economy is invested rather than consumed. We hypothesize that the more investment there is in gross fixed capital, the more modern production methods are, and so we expect greater chances of winning the competition in international markets.

The final determinant of export competitiveness that we choose for our study is intermediate consumption in industry, calculated as the share of intermediate consumption related to production value. Nowadays, the increasing fragmentation of production across borders and the increasing use of foreign inputs can lead to a situation in which a country exports a lot but the value added to the gross value of exports is small (Yuqing 2011, p.9). We expect that the smaller the share of intermediate consumption in the production of a sector is, the more competitive the economy gets.

Trade is spatial by nature, but the international trade literature pays less attention to space. Paul Krugman was the first to present a model of trade between two regions (Krugman 1990, p.8). However, the most popular econometric model in which a determinant of trade flows is the distance between countries is the gravity trade model (Tinbergen 1962, pp.262-293). The greater the distance between countries, the greater the cost of transport and so less trade flows between two countries. The current nature of modern international trade – i.e. production outsourcing, international fragmentation of production processes and the emergence of international production networks – allows us to hypothesize that the strength and direction of exports to one country also depend on the strength and direction of exports to a neighbouring country.

4. Spatial dependence and spatial panel data models

A sample which consists of N cross-sectional observations of individuals over T time periods allows the estimation of a panel data model written as follows:

$$y_{it} = x_{it}\beta + \varepsilon_{it} \quad i = 1,2,...,N \quad t = 1,2,...,T \,, \tag{1}$$

where y_{it} is a NT ×1 vector, x_{it} is a NT × K matrix and the random disturbance ε_{it} is a NT ×1 vector. Random disturbance can be decomposed into individual effects α_i, time effects μ_t, and white noise ξ_{it}. Depending on the character of individual and time effects, they are treated as fixed or random effects.

This form of the model ignores a potentially significant spatial dependence between the objects analyzed, which can lead to misspecification, loss of information that is important for the analysis, and finally to incorrect conclusions. It seems to be crucial to take neighbour dependence into consideration. In spatial econometrics, neighbour dependence is expressed by means of a spatial weight matrix, which shows the interactions between units in different locations. This reflects an influence of unit i on unit j and vice versa. There are several ways of constructing a spatial weight matrix, but the correct selection of the matrix should take the nature of the phenomenon analyzed into account.

A panel data model including spatial interactions is given as:

$$\begin{aligned} y_{it} &= \lambda(W_1 y)_{it} + x_{it}\beta + \alpha_i + \mu_t + \xi_{it} \\ \xi_{it} &= \rho(W_2 \xi)_{it} + u_{it} \end{aligned} \,, \tag{2}$$

where W_1 is a spatial weight matrix which reflects the spatial autoregression of variable y, and W_2 is a spatial weight matrix for the spatial autocorrelation of random disturbance.

Assuming an equality of the spatial processes of the dependent variable and error model, matrices $W_1 = W_2 = W$. Row-standardization results in the parameters of the spatial structure, λ and ρ, belonging to < -1, 1 >.

Taking into consideration all the above-mentioned, the spatial dependence in fixed effects and random effects two-way panel data models are as follows:

1. Spatially lagged endogenous variable with individual effects treated as fixed – SAR FE model:

$$y_{it} = \alpha_i + \mu_t + \lambda(Wy)_{it} + x_{it}\beta + \xi_{it} \tag{3}$$

2. patially autocorrelated error components with individual effects treated as fixed – SE FE model:

$$\begin{aligned} y_{it} &= \alpha_i + \mu_t + x_{it}\beta + \xi_{it} \\ \xi_{it} &= \rho(W\xi)_{it} + u_{it} \end{aligned} \tag{4}$$

3. spatially lagged endogenous variable with individual effects treated as random – SAR RE model:

$$\begin{aligned} y_{it} &= \alpha_0 + \lambda(Wy)_{it} + x_{it}\beta + \varepsilon_{it} \\ \varepsilon_{it} &= \alpha_i + \mu_t + \xi_{it} \\ var(\varepsilon_{it}) &= \sigma_\alpha^2 + \sigma_\mu^2 + \sigma_\xi^2 \end{aligned} \tag{5}$$

4. spatially autocorrelated error components with individual effects treated as random – SE RE model:

$$\begin{aligned} y_{it} &= \alpha_0 + X_{it}^T\beta + \varepsilon_{it} \\ \varepsilon_{it} &= \alpha_i + \mu_t + \xi_{it} \\ \xi_{it} &= \rho(W\xi)_{it} + u_{it} \end{aligned} \tag{6}$$

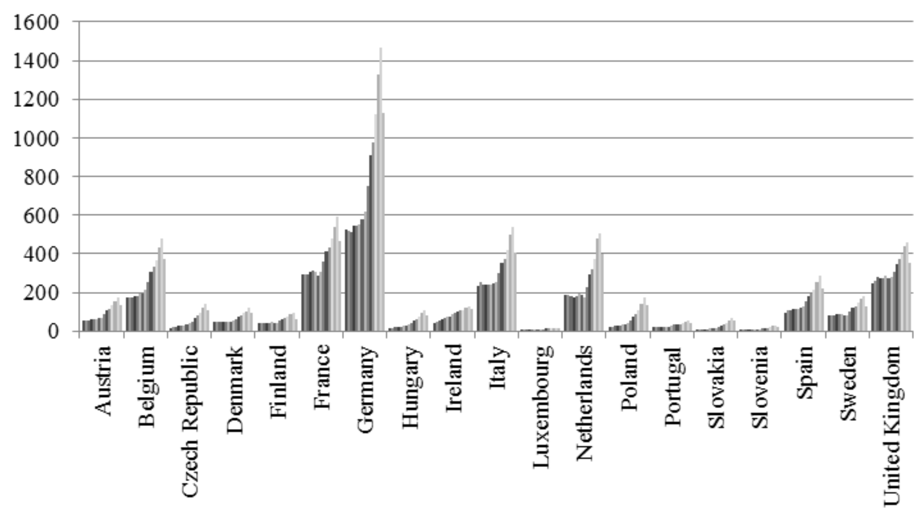
5. Data and Empirical Results

The theory of spatial panel econometrics is employed in order to explain how domestic demand, foreign demand, labour productivity, openness of economy, export prices, intra-industry trade, investment intensity and the intermediate consumption share of production influence the export competitiveness of European economies. As a measure of export competitiveness, we use two variables independently: exports (EXit) and exports in relation to imports (NEXit). Figures 1 and 2 present the endogenous variables over the period 1995-2009.

In this investigation, domestic demand (DDit) is expressed as the sum of the final consumption expenditures of households, non-profit organization serving households and government, fixed capital formation and changes in inventories and valuables. The foreign demand indicator (FDit) is built as the sum of the imports of 34 OECD and selected non-OECD countries from the countries included in the analysis. Labour productivity (LPROit) is measured as the ratio of the gross output of industry to the total hours worked by persons engaged in it. As a measure of openness of the sector (OPENit) we employ the share of exports in the gross value added. Export prices are described by unit labour costs (ULCit). The rest of the variables – intra-industry trade (IITit), investment intensity (IIVAit) and the intermediate consumption share of production (ICSPit) – are taken directly from databases. All data are expressed in U.S. dollars.

Finally, we examine 19 countries[2] using balanced panel data for the period 1995-2009. The sources of the dataset used for the calculation are the OECD STAN Database and the WIOD input-output tables, all data are

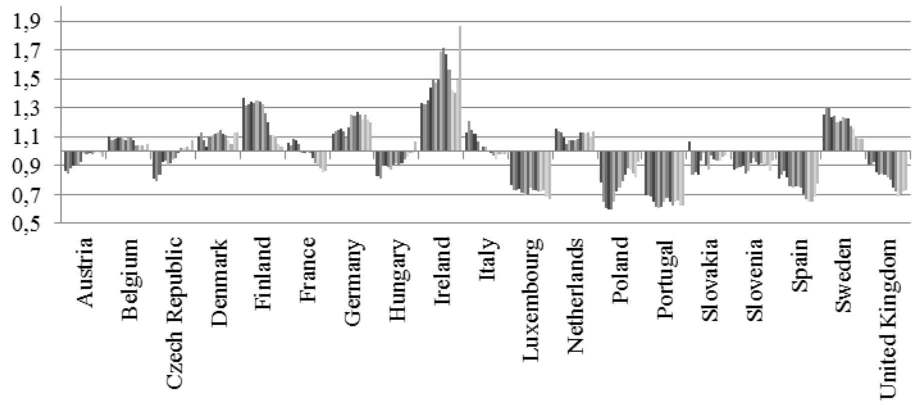
Figure 3. Manufacturing sector exports, in thousands of USD



Source: own elaboration on the basis of the OECD STAN database.

[2] Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

Figure 4. Exports in relation to imports of the manufacturing sector



Source: own elaboration on the basis of the OECD STAN database.

For each variable, we employ a spatial panel data model which is as follows:

$$\begin{aligned} ln\,EX_{it} = \alpha + \beta_1 \,ln\,DD_{it} + \beta_2 \,ln\,FD_{it} + \beta_3 OPEN_{it} + \\ \beta_4 LPRO_{it} + \beta_5 ULC_{it} + \beta_6 IIT_{it} + \beta_7 IIVA_{it} + \beta_8 ICSP_{it} + \varepsilon_{it} \end{aligned} \tag{7}$$

$$\begin{aligned} NEX_{it} = \alpha + \beta_1 \,ln\,DD_{it} + \beta_2 \,ln\,FD_{it} + \beta_3 OPEN_{it} + \\ \beta_4 LPRO_{it} + \beta_5 ULC_{it} + \beta_6 IIT_{it} + \beta_7 IIVA_{it} + \beta_8 ICSP_{it} + \varepsilon_{it} \end{aligned} \tag{8}$$

The investigation begins with estimation of pure panel data models without spatial dependence for both the endogenous variables. This allows us to start by knowing whether we can observe a relationship between the measures of competitiveness and their determinants, which have been chosen on the basis of the literature. The significance of the regressors is confirmed, both for exports and the exports to imports relationship. Additionally, the Hausman test is applied and the hypotheses of consistency of the GLS estimator are rejected. We also test the significance of individual and time effects. Based on the results, we can conclude that a two-way model should be appropriate. The results of the estimations of models (7) and (8) are presented in Table 1.

The next step is the construction of the spatial weight matrix. For both equations we decided to focus on a row-standardized first order queen contiguity matrix. As the analysis of main trade partners shows, the nearest neighbours, especially large economies, can be the most important partners in international trade, the choice of a spatial weight matrix can be treated as economically grounded.

Taking spatial relationships into consideration, different forms of the models are estimated for both variables: the spatial autoregressive fixed effects model, SAR FE, and the spatial autoregressive random effects model, SAR RE, according to formulas (3) and (5); the spatial error fixed effects model, SEM FE, and the spatial error random effects model, SEM RE, according to equations (4) and (6); and, as a control, the SARAR (1,1) model in accordance with equation (2), assuming equality of the spatial weight matrices.

The assumption of two-way influence is rejected in the spatial models. Neither in the SAR models nor in the SE models are time effects significant. As before, a spatial Hausman test allows us to reject the null hypothesis that the GLS estimator is consistent. The choice of the spatial autoregressive model is made on the basis of the results of Baltagi, Song, Jung and Koh LM tests. In the SARAR model, the spatial autocorrelation parameter ρ turns out to be insignificant. To summarize, we estimate one-way spatial autoregressive fixed effects models for both measures of international competitiveness. The results of the estimations are presented in Table 1.

Table 1. Export competitiveness – export equation and export-to-import relationship equations

	export equation				export/import equation			
	two-way FE LSDV		one-way SAR FE ML		two-way FE LSDV		one-way SAR FE ML	
lnDD	0.29979 (7.894)	***	0.18026 (6.797)	***	-0.00298 (-0.137)		-0.02577 (-1.340)	
lnFD	0.29572 (11.850)	***	0.26037 (13.974)	***	0.09647 (6.416)	***	0.04658 (3.585)	***
LPRO	0.00003 (3.086)	***	0.00005 (6.675)	***	0.00001 (2.781)	***	0.00001 (1.474)	
ULC	-1.72954 (-3.270)	***	-1.76190 (-4.253)	***	-3.08285 (-10.180)	***	-2.54130 (-8.602)	***
OPEN	0.01399 (10.480)	***	0.00002 (2.121)	**	-0.000003 (-0.387)		0.00103 (1.433)	
IIT	0.00595 (2.790)	***	0.00553 (3.235)	***	-0.00468 (-3.952)	***	-0.00536 (-4.233)	***
IIVA	0.00082 (0.344)		-0.00476 (-2.499)	**	-0.00499 (-3.585)	***	-0.00371 (-2.733)	***
ICSP	-0.00954 (-1.353)		-0.00558 (-1.199)		-0.01651 (-3.972)	***	-0.02851 (-9.026)	***
intercept	9.46288 (12.550)	***	1.74293 (6.164)	***	9.46288 (12.550)	***	3.13118 (11.715)	***
lambda	-	-	0.55171 (20.409)	***	-	-	0.17656 (3.611)	***

significant at 10 % level, ** significant at 5 % level, *** significant at 1 % level, ( ) is the *t* statistics

Source: own calculations.

6. Conclusion

This paper has employed spatial econometrics to explain how total export competitiveness depends on domestic demand, foreign demand, labour productivity, unit labour costs, openness of the economy, intra-industry trade, investment intensity and intermediate consumption in the manufacturing sector. The results for 19 EU countries over 15 years (1995 – 2009) indicate a strong influence of chosen variables, characterized manufacturing sector on total export competitiveness of the analized UE countries.

On the basis of the results, we can confirm that taking the influence of the local neighbourhood into account in the regressions shows that this is a statistically significant factor, affecting both total export value and exports in relation to imports. This means that an increase in the export value of neighbouring economies will influence export growth.

Comparing the estimations of both regressions, we find that the determinants of exports and of the ratio of exports to imports are different. The only common significant variables are foreign demand and unit labour costs. Moreover, the direction of influence does not change regardless of the model. If we measure the export competitiveness by the export value, we can state that an increase of domestic demand, foreign demand, labour productivity, openness of the economy, intra-industry trade promotes the competitiveness growth, as well as an decrease of unit labour costs in the manufacturing sector. Based on export/ import relation as the competitiveness indice we find that only the growth of foreign demand and labour productivity causes the competitivess growth, as the decrease in intra-industry trade, in the investment intensity and in the intermediate consumption in the manufacturing sector.

It would be interesting for future research to use differently weighted matrices which would capture cross-country interdependence in other ways. Another direction of future research could involve the use of a spatial cross-regressive model, allowing the evaluation of the impact of spatially lagged exogenous variables on the phenomena studied here. Focusing on the cross-sectional dimension of the data analyzed, the time dimension and possible non-stationary data should also be taken into consideration.

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Streszczenie

WPŁYW SEKTORA PRZEMYSŁU PRZETWÓRCZEGO NA KONKURENCYJNOŚĆ EKSPORTU WYBRANYCH KRAJÓW UNII EUROPEJSKIEJ - PRZESTRZENNA ANALIZA PANELOWA

Celem niniejszej pracy jest określenie, przy użyciu przestrzennego modelu panelowego, w jaki sposób zmiany w konkurencyjności eksportu wybranych gospodarek Unii Europejskiej, mierzone wielkością eksportu i eksportu netto, zależą od zmian w konkurencyjności przemysłu przetwórczego. Determinanty konkurencyjności eksportu zostały wybrane w świetle dorobku teorii handlu międzynarodowego, teorii wzrostu i teorii innowacji. W szczególności, autorzy chcieli zbadać, w jakim stopniu wielkość popytu zagranicznego, wielkość popytu krajowego, poziom jednostkowych kosztów pracy, stopień otwartości na rynki zagraniczne, wydajność pracy i zużycie pośrednie w sektorze przemysłowym wpływają na konkurencyjność eksportu wybranych gospodarek europejskich. Wyniki przeprowadzonej analizy wskazują na istotnie statystyczne zależności przestrzenne w modelowaniu konkurencyjności eksportu. Analiza wskazała również na nieznacznie odmienne determinanty konkurencyjności eksportu mierzonego wielkością wywozu (jednostkowe koszty pracy, popyt krajowy, popyt zagraniczny) i analizowanego przez pryzmat eksportu netto (jednostkowe koszty pracy, popyt zagraniczny, zużycie pośrednie).

Słowa kluczowe: *handel międzynarodowy, konkurencyjność eksportu, produkcji, przestrzenny model danych, Unia Europejska*

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Regional Innovativeness Strategies And Their Impact On Innovativeness Of Provinces In Poland. A Spatio-temporal Analysis

Abstract

Regional Innovation Strategies (RIS) have existed in Poland for almost ten years and in this period they have been developed, accepted and implemented in all provinces. The basic aim of Regional Innovativeness Strategies is to support regional or local authorities and other regional development organizations in defining and implementing an effective system of supporting innovativeness in the region. The current scope of realizing projects connected with RIS is different in particular provinces. The author of the paper attempts to evaluate the effects of implementation of pro-innovativeness solution included in Regional Innovation Strategies with particular consideration of their influence on the growth of region innovativeness level in Poland.

Keywords*: Regional Innovation Strategies, regions innovativeness in Poland, Composite Indicator of Provinces Innovativeness, spatio-temporal analysis*

1. Introduction

Innovations play a leading role in the creation of economic growth on the national and regional level. However, from the enterprise point of view they are recognized as a basic factor of their development and gaining a competitive

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advantage. The relationship between innovations and regional development has been explained in numerous studies describing the importance of economic growth and development.[1]

The awareness of the dependence between a region innovativeness and its development forces local governments to create the innovative policy, which supports activity of domestic enterprises in the scope of undertaking and implementing innovative solutions in enterprises such as technological, managerial, information flow and marketing ones.

The basic tool of implementing the innovative policy on the regional level are Regional Innovativeness Strategies (RIS). Regional Innovativeness Strategies (RIS) have existed in Poland for almost ten years and in this period they have been developed, approved and implemented in all the provinces. The basic aim of Regional Innovativeness Strategies is to support regional or local authorities and other regional development organizations in defining and implementing an effective system of supporting innovativeness in the region. The strategy is created on the basis of the analysis of technological needs, capacity and potential of the research and scientific sector as well as enterprises in the scope of management, finances, training, organization and technology itself. The strategy determines directions of innovative policy and ways of building and optimizing a regional infrastructure supporting innovativeness[2].

The current scope of implementing projects connected with RIS is different in particular provinces. The author of the paper attempts to evaluate the effects of pro-innovativeness solutions implementation included in Regional Innovation Strategies with particular consideration of their influence on the growth of region innovativeness level in Poland.

The study comprised all 16 provinces (regions) in Poland in the period between 2005 to 2012. The paper discusses basic aims and assumptions of Regional Innovativeness Strategies in particular provinces.

[1] A wide list of publications describing the relationships between regional development and innovations can be found in the publication: Świadek A., *Regional innovative system in the European Union*, [in:] Janasz W. (ed.) *Innovations in enterprises operations in integration with the European Union*, Difin, Warszawa 2005, p. 86.

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2. Innovativeness as a basis of social-economic region development

Regional development depends on numerous factors connected with current realities of social-economic life in Poland. The most important ones include: human, material, financial and social capital, technological and organizational innovations and external flows of people, capital and goods (Churski 2008, pp. 66-72).

The role of innovations in the process of development and social-economic progress is particularly important as innovations constitute an indispensible condition of dynamic and effective economy development (Firlej 2012, pp. 143-144). Economists assess that as much as 2/3 of the economic growth of developed countries should be associated with introduction of innovations (Kozioł 2005, p. 132).

The term innovations is a fairly general one. There is no single definition characterizing the described issue and the changes undergoing in the world which surrounds us cause that the subject scope of innovations is getting wide and wider. In the economic literature we can encounter two approaches to interpreting (defining) innovations, i.e. in the broad sense (sensu largo) and the narrow sense (sensu stricto). In the broad grasp (global one) innovation is defined as any change in production consisting in acquisition of obtained knowledge. In the stricto sense grasp innovations are identified only with changes in products and manufacturing methods. We encounter the broad grasp of innovations in publications and reports issued by the OECD or Eurostat where innovations are recognized as introduction of a new largely improved product (good or service), process, new marketing method or a new organization method in the business practice at the workplace and external relationships (Oslo Manual 2005). In the stricto sense grasp innovations are defined by K. Szatkowski who states that under the term innovations we understand changes consisting in improving or replacing existing products, manufacturing methods, manufacturing means, work organization methods and work tools (Szatkowski 2001, p. 25). In such a grasp of innovations the ones connected with social and organizational changes are omitted, concentrating on the technological ones. This results primarily from the fact that the scope of technological changes in the largest extent determines transformations in the manufacturing process and economic development.

The condition of innovations occurrence is the presence of propensity and possibility to implement them, i.e. innovativeness. Innovativeness is an economic category which can be discussed and defined on three different levels, namely, on the level of enterprise, region and state (economy). Under the term enterprise innovativeness we should understand their ability to create and implement innovations and the real capability of the enterprise to introduce new and modernized products, new or modernized technological or organizational-technological processes. Economy innovativeness in turn is defined as the ability and motivation of enterprises to constantly seek for and use in practice results of scientific research, new ideas, concepts and inventions. Innovativeness also means improvement and development of existing production technologies, introduction of new or improved solutions in organization and management as well as improvement of information processing, gathering and making it available (Kierunki zwiększania innowacyjności gospodarki na lata 2007–2013, 2006, p. 6). Economy innovativeness depends on innovativeness of its particular regions, the level of region innovativeness in turn is dependent on innovative activeness of economic subjects located in the particular territorial area.

In the subject literature the role of regions in creating a proper innovative environment (innovative policy) is stressed more and more often. The regional grasp of innovativeness and its influence on the development of regions seems to be the right one, first of all because of very well developed awareness of being a member of a given community in the European reality - local patriotism. In some countries it results from the political structure, in the others it is conditioned historically or geographically (Szajt 2007, p. 71). A region, through its specific resources, which may include: knowledge resource, ability to learn, organizational culture, infrastructure and many others, influences the competiveness of local enterprises and their innovative activeness. These competitive advantages of the local nature come from concentration of highly specialized knowledge, presence of public institutions, competition, business partners, consumers (Porter 2003, pp. 549-578).

Innovations, as so called soft factors, fulfil the role of a vital stimulus in the process of region social-economic development, and thus they have influence on their competitiveness improvement. Under the term region competitiveness we should understand an advantage over other regions, being the product of service offer attractiveness directed at present and potential region users, who are the inhabitants, companies, investors and guests, and its source is modern material, institutional and intellectual infrastructure of the region (Klasik, Markowski 2002, pp. 99-100).

Innovations influence improvement of region competitiveness in two ways. Firstly, they result in organizational changes, changes of manufacturing methods and marketing strategies, the effect of which is production efficiency improvement. Secondly, the result of their realization is introducing a new or largely improved product to the market (Golejewska 2012, p. 34).

Region competitiveness may be manifested in direct and indirect competition (Markowski, Marszał 1998, p. 133). From the point of view of enterprises and growth of their innovativeness what seems more important is indirect competition, which comes down to building regional environment conditions for enterprises functioning in it in order to obtain competitive advantage in the aspects which are beyond the subjects control. Enterprises owe their innovativeness not only to their own organizational abilities, but also to the external environment in which they function, including the institutions on regional and local level (Golejewska 2012, p. 36).

3. Regional Innovativeness Strategies in Poland

Strategies should be understood as a consciously assumed and consequently realized in a longer time horizon way of maintaining constant competitive advantage by an organization, a region, a country (Koźmiński 1999, p. 97).

In various definitions of strategies we can distinguish several reoccurring issues (Marchesnay 1994, pp. 12-13):

- issue of goals - which is recognized as every behaviour focusing on formulation of long-term goals,
- plan issues - strategic are all activities at the basis of which lies planning to use resources in a longer time horizon,
- environment level - any behaviour is strategic if it leads to obtaining a constant competitive advantage in a long period with reference to the competitive environment,
- issues and scope of a change - decisions that cause vital structural changes and changes in the management domain.

In case of innovative strategies one can state that this is a set of main decisions in the following areas of operation (Kieżun 1997, p. 97):

- choice of the basic direction in the scope of shaping a triple possibility: the product, the market and the technologies,
- determining quantitative goals in the following domains: economic one, technological one and social-political one,
- gathering and allocating financial and technical resources as well as the staff which makes it possible to realize the intended tasks.

Regional Innovativeness Strategies (RIS) are a tool of shaping the innovative policy and building an effective system of innovativeness support in the region. They constitute the foundation of creating cooperation and partnership of all regional actors creating and supporting the course of innovative processes. RIS constitute the basis of building efficient regional innovativeness systems, and first of all the basis for using the European Union's funds for activities of innovative nature (Nowakowska 2007, p. 204). A regional innovativeness system is a set of interactions taking place among the knowledge domain, R+D sector, economic subjects, education system, finances and public authorities, facilitating processes of adaptation and collective learning (Nowakowska 2007, pp. 302-303).

In accordance with the guidelines of the European Union the most important principles of building regional innovativeness strategies are (Wieloński, Szmigiel 2006, p. 20):

- partnership and public-private consensus (at all stages of work),
- stress on the demand side and the bottom-up approach at their development,
- orientation on activities (they should contain a plan, but also projects),
- making the use of European dimension,
- cyclicity.

As a basic factor in creating a proper innovativeness policy in the region, regional innovativeness strategies should contain at least three areas:

- development of innovativeness and entrepreneurship centres,
- development of financing instruments of a new enterprise and risky innovative ventures,
- stimulating and promoting technological entrepreneurship.

In addition, they should comprise four groups of supporters:

- businessmen,
- business environment institutions,
- research-development units (RDU, presently: research institutes) and universities,
- local governments.

Table 1 presents basic goals of RIS developed by individual regional governments in order to improve their innovativeness level and what follows, their competitiveness.

Table 1. Basic goals of Regional Innovativeness Strategies in Poland

Province/Straregy	Basic goals
Dolnośląskie Dolnośląska Innovations Strategy	- supporting regional entrepreneurship clusters, - real support of the regional innovativeness system by the scientific-research facilities, - building the innovative infrastructure supporting both incubation processes and processes of innovations commercialization, - use of present resources to create a system of innovations financing (lack of legislative solutions on the national level makes it impossible to create such a system from scratch), - lowering the barriers for operations of innovators,

	- education for innovations through thorough changes of the existing education model, - promoting innovative successes, rewarding innovations authors and in particular setting goals which require an innovative approach.
Kujawsko-Pomorskie Regional Innovativeness Strategy of Kujawsko-Pomorskie Province until the year 2015	- development of enterprises towards knowledge-based economy through e-business development, supporting restructuring traditional economy areas to meet the contemporary requirements, more efficient attracting of investors from the high-tech technologies area, - building an effective system of cooperation between economy and knowledge in the region, in which the scientific-research centres realize expectations of enterprises and create new products, - pro-innovative business environment consisting of four systems comprising: common access to information for enterprises, network of institutions acting for innovativeness, pro-innovative system of education, pro-innovative climate and a way of operation of government in the region.
Lubelskie Regional Innovativeness Strategy of Lubelskie Province, Innovative Lubelszczyzna – Transforming Ideas into Actions	- growth of entrepreneurship in the region - improved effectiveness of classic agriculture, - development of organic products sector, - growth of competitiveness of scientific-didactic offer.
Lubuskie Regional Innovativeness Strategy of Lubuskie Province	- making the use of knowledge potential and R+D for the growth of the region's economy competitiveness, - building a system supporting innovations and modern innovative infrastructure in the region, - supporting entrepreneurship and innovative activity of enterprises.
Łódzkie Regional Innovativeness Strategy of Łódź Province – RIS LORIS 2005 - 2013	- increase in expenditures on R+D, - increase in regional R+D potential effectiveness, - creating conditions facilitating high-tech industries development, - significant increase in the level of knowledge-intensiveness of traditional industries and agriculture, - development of information society services and knowledge-based economy.
Małopolskie Regional Innovativeness Strategy of Małopolskie Province 2008-2013	- increase in innovativeness of enterprises in the province, through, among others, developing tools supporting financing of innovative activity of enterprises and increased participation of enterprises and research institutions in international research-development programmes and transfer of technologies, - reinforcing network contacts of institutions connected with the region innovativeness and a better use of their potential, - increased importance of innovativeness in regional policy.

Mazowieckie Regional Innovativeness Strategy for Mazowsze 2007-2015	- cooperation increase in the processes of innovations and innovativeness development, - growth in internalization of Mazowieckie province enterprises, - growth of resources and effectiveness of financing pro-innovative activities in the region, - shaping and promoting pro-innovative and pro-entrepreneurial attitudes in the regions.
Opolskie Regional Innovativeness Strategy of Opolskie Province 2004-2013	- creating an effective regional system of innovativeness support - increased use of the potential of scientific-research institution in the province, - increase enterprises competitiveness in the region through an increase in innovativeness of enterprises from the Small and Medium Enterprises sector.
Podkarpackie Regional Innovativeness Strategy of Podkarpackie Province for the years 2005-2013	- open and effective network of creating and supporting innovativeness, - increase in the potential of educational institutions, - strengthening innovative enterprises in the region and creating new ones.
Podlaskie Regional Innovativeness Strategy of Podlaskie Province 2005-2013	- strengthening the Podlasie economy competitiveness through innovations, - establishing institutional mechanisms of innovativeness support of Podlaskie province, - pro-innovative transformation of scientific-research institutions potential in Podlaskie province,
Pomorskie Regional Innovativeness Strategy of Pomorskie Province (RIS-P)	- building consensus and partnership for the development of information society and innovativeness in the region, - shaping innovative culture and pro-innovative education, - supporting development of the area outside the Tri-City agglomeration through innovations, - supporting the development of Small and Medium Enterprises in the region through the use of innovative potential of the Tri-City agglomeration.
Śląskie Regional Innovativeness Strategy of Śląskie Province for the years 2003-2013	- increased share of high innovativeness enterprises in the total number of small and medium enterprises, - increased use of research-development potential, - ensuring an effective Regional Innovativeness System based on mutual trust, creativity and perfection.
Świętokrzyskie Regional Innovativeness Strategy of Świętokrzyskie Province for the years 2005-2013	- improving educational system which shapes open, innovative and entrepreneurial attitudes - development of research activity in order to trigger internal factors of region development, - building the infrastructure of information society, - development of business environment institutions,

	- building institutional forms of cooperation among academic environment, regional governments and economy, - optimum use of the EU funds for implementing RIS.
Warmińsko-Mazurskie Regional Innovativeness Strategy of Warmińsko-Mazurskie Province	- growth of qualifications, - promoting high quality, - promoting cooperation, - building innovative potential.
Wielkopolskie Regional Innovativeness Strategy "Innovative Wielkopolska"	- integrating social-economic communities for innovations, - increasing the capacity of enterprises to introduce innovations, - making use of the research potential of Wielkopolska for economy competitiveness growth, - building modern innovative infrastructure.
Zachodniopomorskie Regional Innovativeness Strategy in Zachodniopomorskie Province	- growth of innovative awareness of Small and Medium Enterprises, - creating conditions for development of technology and innovations market in the region, - developing a support system for innovative actions in the region.

Source: Own elaboration on the basis of Regional Innovativeness Strategies in individual provinces.

Regional Innovativeness Strategies in Poland have been approved by local government assemblies of all provinces. The first strategies were developed and approved in the provinces of Zachodniopomorskie, Wielkopolskie, Śląskie, Opolskie and Warmińsko-Mazurskie. The last provincial local government where RIS was elaborated was Mazowsze region.

It ensues from the studies concerning Regional Innovativeness Strategies (Regionalne Systemy Innowacji w Polsce. Raport z badań, 2013, pp. 59-70) that the provisions of all regional innovativeness strategies indicate their completeness. The goals of RIS most frequently and to the largest extent concentrate on interventions in the areas connected with development of innovativeness and entrepreneurship centres as well as stimulating and promoting technological entrepreneurship. Less emphasis is put on creating the instruments of financing tools of new enterprises and risky innovative ventures (lack of such goals in RIS of the provinces: Łódzkie, Mazowieckie, Śląskie, Wielkopolskie). The provinces of Podkarpackie and Zachodniopomorskie stand out positively in this respect as they put particular emphasis on these instruments. As a rule all RIS include beneficiaries from all groups of supporters in their impact. In some regions (Łódzkie, Podlaskie, Śląskie, Wielkopolskie) RIS to a small extent or do not include at all the intervention of the local government of the province.

4. The analysis of Polish provinces innovativeness level in the years 2005-2012

Evaluation of the economy innovativeness level or its particular regions is conducted on the basis of direct and indirect indicators. Indirect indicators are based on intensity of research-development works. They measure the results of inventive activity and on the basis of them conclusions concerning the innovative situation of a country or a region are formulated. Direct indicators in turn concentrate on the effects of product, process, organizational and marketing innovations (Nowak 2012, pp. 153-154).

In order to evaluate innovativeness level of provinces in Poland the author has chosen nine indicators. Data comes from the Local Data Bank published by the Central Statistical Office. The following set of variables have been proposed:

X1 – the number of centres conducting research-development activity,

X2 – share of individuals employed in R+D in total number of working individuals (in percentage) ,

X3 – internal expenditures on research-development activity calculated per one individual employed in R+D,

X4 – expenditures of an enterprise on research and development as a percentage of GNP,

X5 – expenditures in the higher education sector on research and development as a percentage of GNP,

X6 – enterprises, which incurred expenditures on innovative activity as a percentage of all enterprises,

X7 – innovative enterprises, which in the given year launched at least one product or process innovation to the market, as a percentage of all enterprises,

X8 – share of the production of sold new/substantially improved products in industrial establishments in the total value of product sale,

X9 – registered inventions and granted patents calculated per 1000 individuals employed in R+D.

The presented variables have been used to determine the Composite Indicator of Provinces Innovativeness (CIPI), which has been determined as arithmetic mean from the normalized primary variables:

$$s_t = \frac{1}{n}\sum_{i=1}^{n} z_{it} \qquad (1)$$

where: st – synthetic measure for i – th province in t period, $\sum_{i=1}^{n} z_{it}$ - sum of normalized values of diagnostic variables in i-th province in t period, n - number of provinces.

The applied normalization method was the benchmark normalization. As the benchmark the author used the maximum value of the diagnostic variable x_{jt} $j \in \{1,2,...,m\}$ $t \in \{1,2,...,k\}$ for provinces in the given time moment t

$$z_{ijt} = \frac{x_{ijt}}{\max_i x_{ijt}}, \quad \max_i x_{ij} \neq 0 \;\; i \in \{1,2,...,n\}; \;\; j \in \{1,2,...,m\}; \;\; t \in \{1,2,...,k\} \quad (2)$$

The values of the Composite Indicator of Provinces Innovativeness for particular regions of Poland and their basic measures of central tendency and differentiation have been summarized in Table 2.

The values of the innovativeness measure indicate that in the analyzed period Mazowieckie, Małopolskie and Pomorskie provinces were characterized by the highest innovativeness level. On the other hand, these are also the regions where the highest rate of decrease in innovativeness level occurs, measured year-over-year. The province whose innovativeness level is characterized by the highest growth rate is Świętokrzyskie province, for which the value of the innovativeness indicator grew year-over-year on average by 7,4%.

Regions of the highest innovativeness level proved to be least resistant to economic slowdown, caused by the world economic crisis, which in Poland dates back to years 2009-2011. In Mazowiecki, Małopolski, Pomorski, Dolnośląski and Śląski regions one can observe a clear decrease in the value of innovativeness indicator after the year 2009.

A positive phenomenon that can be observed in the years 2006-2012 is a decrease in the differentiation of provinces innovativeness level in Poland. The value of the coefficient of variation in this period dropped from the level of 30,9% to 18,7%. Still the value of the coefficient demonstrates a distinct differentiation in the innovativeness level of provinces, but the differences are becoming smaller. This phenomenon may confirm the effectiveness of actions taken at the central and regional level both within the confines of Regional Innovativeness Strategies as well as in the scope of the innovative policy and sustainable regional development in Poland.

Table 2. Values of the Composite Indicator of Provinces Innovativeness in the years 2006 – 2012

PROVINCE	YEAR							Average change rate of the phenomenon in time [%]
	2006	2007	2008	2009	2010	2011	2012	
ŁÓDZKIE	0,466	0,446	0,443	0,478	0,456	0,435	0,432	-1,3
MAZOWIECKIE	*0,862*	*0,853*	*0,884*	*0,761*	*0,711*	*0,670*	*0,620*	*-5,4*
MAŁOPOLSKIE	*0,663*	*0,672*	*0,707*	*0,669*	*0,609*	*0,618*	*0,574*	*-2,4*
ŚLĄSKIE	0,558	0,576	0,532	0,656	0,583	0,515	0,514	-1,4
LUBELSKIE	0,447	0,463	0,461	0,484	0,456	0,495	0,488	1,5
PODKARPACKIE	0,572	0,555	0,510	0,559	0,622	0,645	0,528	-1,3
PODLASKIE	0,414	0,352	0,435	0,373	0,384	0,383	0,411	-0,1
ŚWIĘTOKRZYSKIE	0,304	0,341	0,428	0,477	0,439	0,429	0,466	7,4
LUBUSKIE	0,282	0,283	0,294	0,341	0,305	0,307	0,301	1,1
WIELKOPOLSKIE	0,465	0,524	0,523	0,572	0,510	0,546	0,502	1,3
ZACHODNIOPOMORSKIE	0,340	0,357	0,389	0,407	0,412	0,400	0,373	1,6
DOLNOŚLĄSKIE	0,496	0,528	0,581	0,612	0,535	0,511	0,534	1,3
OPOLSKIE	0,382	0,351	0,353	0,453	0,401	0,466	0,394	0,9
KUJAWSKO-POMORSKIE	0,447	0,371	0,428	0,477	0,424	0,412	0,390	-2,3
POMORSKIE	*0,676*	*0,613*	*0,673*	*0,637*	*0,597*	*0,593*	*0,582*	*-2,5*
WARMIŃSKO-MAZURSKIE	0,345	0,446	0,374	0,400	0,426	0,359	0,365	0,9
Descriptive statistics								
Arithmetic mean	0,482	0,483	0,501	0,522	0,492	0,487	0,467	
Median	0,456	0,455	0,452	0,481	0,456	0,481	0,477	
Coefficient of variation in [%]	30,9	29,9	29,1	22,3	21,3	21,3	18,7	

Source: own calculations on the basis of the Local Data Bank of CSO.

5. Conclusions

Regional Innovativeness Strategies have already almost a 10-year history in Poland. These strategies determine the directions of the innovative policy and the ways of building and optimizing regional infrastructure facilitating innovativeness. As any activity, especially the one of strategic meaning, developed in a dynamically changing environment RIS are not free of some imperfections. The following, most frequently occurring imperfections may be indicated in Regional Innovativeness Strategies (Regionalne Systemy Innowacji w Polsce. Raport z badań, 2013, p. 63):

- goals are not always precisely defined and are not quantified,
- in many cases not all actions have defined terms, contractors and financing sources,
- not always a proper structure of goals has been applied, distinguishing at least three levels of goals,
- most frequently they lack prioritizing of tasks,
- not always a monitoring system of goals realization have been foreseen, or even goals implementing indicators.

However, as a basic tool of creating an innovation policy in the region RIS undoubtedly have influence on positive changes that take place in level of the region innovativeness in Poland. This influence can be most clearly perceived in case of provinces such as Świętokrzyskie or Opolskie, where the innovativeness level of these regions has improved substantially in the years 2006-2012. Another positive change which can be observed in the innovativeness level of provinces is that the disparities in the innovativeness level of individual regions are blurring.

A big advantage of RIS is the fact that unlike earlier developed programmes whose task was to support innovative activity, all goals included in RIS in each province find financing sources determined in the operational programmes for these provinces for the years 2007-2013.

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Streszczenie

REGIONALNE STRATEGIE INNOWACJI I ICH WPŁYW NA INNOWACYJNOŚĆ WOJEWÓDZTW W POLSCE – ANALIZA PRZESTRZENNO-CZASOWA

Regionalne Strategie Innowacji (RSI) istnieją w Polsce blisko dziesięć lat i w tym okresie zostały one opracowane, przyjęte i wdrożone we wszystkich województwach. Podstawowym celem Regionalnych Strategii Innowacji jest wspomaganie władz regionalnych lub lokalnych oraz innych organizacji rozwoju regionalnego w zdefiniowaniu i wdrożeniu efektywnego systemu wspierania innowacyjności w regionie. Dotychczasowy zakres realizacji projektów związanych z RSI jest różny w poszczególnych województwach. W pracy podjęto próbę oceny efektów wdrażania rozwiązań proinnowacyjnych zawartych w Regionalnych Strategiach Innowacji ze szczególnym uwzględnieniem ich wpływu na wzrost poziomu innowacyjności regionów w Polsce.

Słowa kluczowe: *Regionalne Strategie Innowacji, innowacyjność regionów w Polsce, syntetyczny wskaźnik innowacyjności regionów, analiza przestrzenno - czasowa*

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KAROLINA LEWANDOWSKA-GWARDA*

Spatial Analysis Of Foreign Migration In Poland In 2012 Using Geographically Weighted Regression

Abstract

Migration has a principal influence on countries' population changes. Thus, the issues connected with the causes, effects and directions of people's movements are a common topic of political and academic discussions.

The aim of this paper is to analyse the spatial distribution of officially registered foreign migration in Poland in 2012. GIS tools are implemented for data visualization and statistical analysis. Geographically weighted regression (GWR) is used to estimate the impact of unemployment, wages and other socio-economic variables on the foreign emigration and immigration measure. GWR provides spatially varying estimates of model parameters that can be presented on a map, giving a useful graphical representation of spatially varying relationships.

Keywords: *emigration,immigration, spatial analysis, GIS, GWR*

1. Introduction

Agreements signed in the scope of the free movement of people, which is one of the fundamental human freedoms, are currently respected almost throughout the whole of Europe[1]. Nowadays the signatories of the Schengen

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[1] http://ec.europa.eu/dgs/home-affairs/pdf/flipbook/ (accessed on 21 May 2014).

Agreement, under which border checks are gradually abolished at the signatories' common borders, are twenty-two European Union countries as well as Iceland and Norway. Switzerland and Liechtenstein are associated with the Schengen group. Cyprus, Croatia, Bulgaria and Romania are seeking membership. The abolishment of institutional barriers has increased migration processes in Europe leading to numerous positive as well as negative consequences. People's migrations affect, to a large extent, the sizes of populations in European countries. Therefore, issues connected with causes, effects and directions of the movements of people are becoming an increasingly frequent topic of political and academic discussions.

Poland joined the European Union in 2004 and became the signatory of the Schengen Agreement in 2007 but it was only in 2011 and 2014 that the last barriers to the free movement of citizens were eliminated[2]. According to unofficial data, as many as 2.7 million Poles may be currently residing abroad[3]. Given the fact that those are usually young people, often having higher education it definitely poses a serious problem to the country. Emigration substantially exceeds immigration. Along with Romania and Bulgaria, Poland is characterized by the lowest share of foreigners in the overall population.

Causes of migration are very complex and difficult to define. Main factors leading to the movements of people include environmental, psychological, political, cultural and economic aspects. It should be emphasized that they can co-occur (Bonifazi, Okólski, Schoorl, Simon 2008, p.13). For Poles the most important ones are socio-economic aspects connected with seeking better living conditions – stability, safety and better working culture. The proximity of the country of migration and historical factors are also important (GUS 2013, p. 1).

The aim of this article is to analyse the spatial distribution of immigration and emigration[4] in Poland. The study was carried out on officially registrered statistical data concerning poviats in 2012, published by the Central Statistical Office. The first part of the study used geographic information systems tools for the purpose of the visualization and preliminary (statistical) data analysis. Then, an attempt was made to specify socio-economic variables that might significantly

[2] As the last EU members, Germany and Austria opened their labour markets to Poles on 1 May 2011, while Switzerland – a signatory of the Schengen Agreement – did that on 1 May 2014.

[3]http://www.fronda.pl/a/kolejna-wielka-emigracja-polakow-w-2013-wyjechalo-z-polski-pra wiepol-miliona,34385.html (accessed on 20 May 2014).

[4] According to the Central Statistical Office: immigration – registration for permanent residence of individuals coming from abroad; emigration – de-registration for permanent residence abroad.

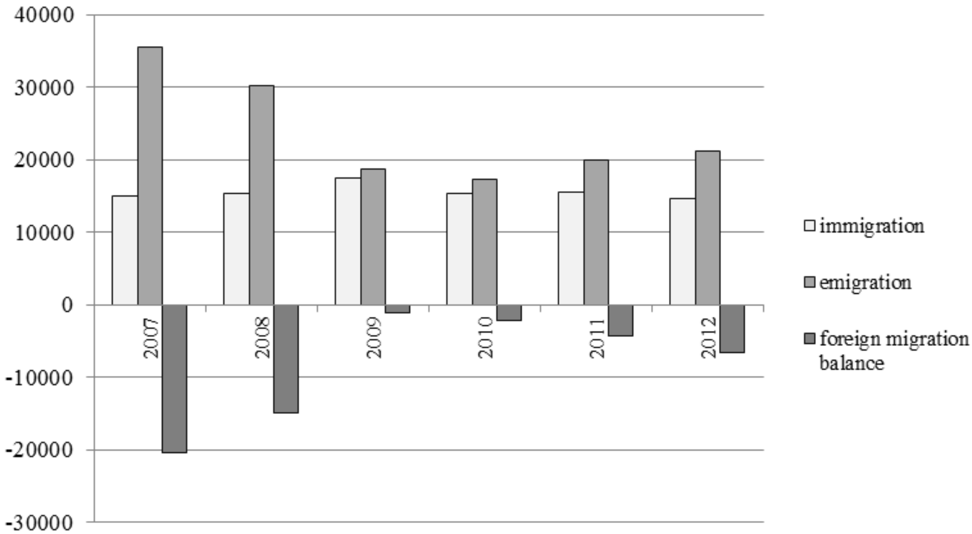
affect migration in Poland. The analysis of impacts of exogenous variables on immigration and emigration applied geographically weighted regression allowing to identify variability of regression coefficients in geographical space.

2. Foreign migration in Poland

Figure 1 shows immigration (inflow of people), emigration (outflow of people) and net migration (difference between immigration and emigration) in Poland in the years 2007-2012. The largest volume of emigration was reported in 2007 and 2008 when over 65000 people emigrated from Poland. In 2009 the volume of emigration markedly decreased; the trend continued in 2010 as well. In turn, in 2011 and 2012, the variable showed a considerable rise again.

The inflow of foreign population ran at about 15000 people per year; it was only in 2009 that a slight increase in that variable was observed. The net migration was negative throughout the study period, which meant that emigration exceeded immigration. The largest differences between the inflow and outflow of people were reported in 2007 and 2008. Those significantly decreased in 2009 to go up again in the final three years of the study, in particular, in 2012. Thus, it can be noted that the first substantial wave of Poles' emigration occurred before the economic crisis, i.e. in the years 2007-2008. At present, when the economic situation of European countries gradually stabilizes and effects of the crisis subside, the second growing wave of Poles' emigration is observed. According to the reports published by the Central Statistical Office, a vast majority of emigrants from Poland reside in the countries of the European Union, especially in the United Kingdom, Germany, Ireland, the Netherlands and Italy. There is also a rise in the number of people emigrating to Scandinavian countries (GUS 2013, pp. 3-4). As for immigrants, most of them are citizens of Ukraine, Vietnam, Russia and Belarus.

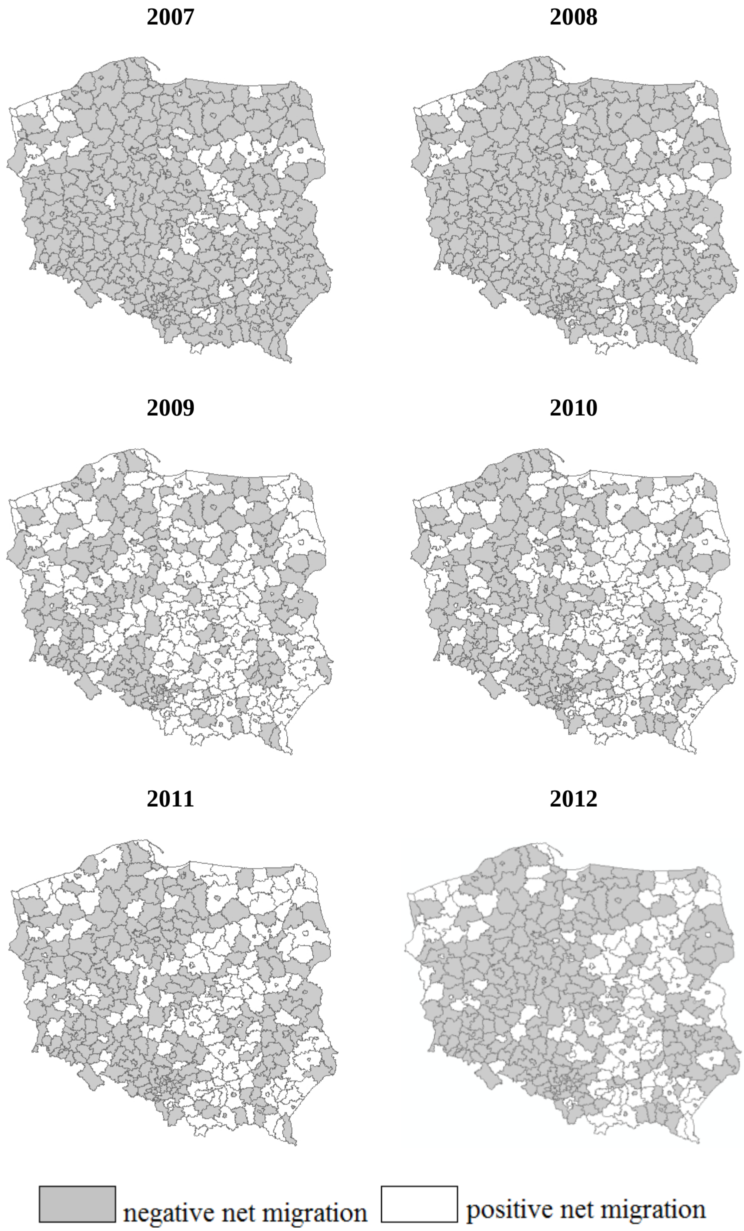
Figure 1. Foreign migration in Poland in the 2007-2012 period



Source: own work based on statistical data of the Central Statistical Office.

Figure 2 shows net migration for specific poviats of Poland between 2007-2012. In the first year of analysis a positive net migration occurred only in 50 poviats. The lowest value of the variable was observed in the Opolski (-650) and Gliwicki (-591) poviats, while the highest – in Warsaw (103) and Cracow (91). In 2008 the number of spatial objects characterized by a positive net migration rose to 61 and in 2009 it was as high as 214. At that time, the highest value of the variable was reported in Warsaw (480) and Wrocław (422). In the years 2010-2012 there was a gradual increase in the share of poviats with a negative net migration. In 2012 a positive net migration occurred in only 133 spatial units. The lowest value of the variable was observed in the Opolski (-361) and Strzelecki (-291) poviats, while the highest – in Warsaw (255) and Cracow (228). A map for 2012 shows a clear division into Western Poland characterized, to a large extent, by a negative net migration, and Eastern Poland where poviats with a positive external net migration are located.

Figure 2. Foreign migration balance in poviats in 2007-2012



Source: own work in ArcMap, based on statistical data of the Central Statistical Office.

3. GWR in migration analysis

The conventional approach to the empirical analyses of spatial data is to build a global model that assumes homogeneous (stationary) across-space relationships between dependent and independent variables. It means that the same stimulus provokes the same response in all parts of the study region (countries, voivodeships, poviats). The regression equation can be expressed as:

$$y_i = \beta_0 + \sum \beta_{ik} x_{ik} + \varepsilon_i, \tag{1}$$

where: yi - dependent variable, β i - coefficients, xik – independent variables, εi - error term.

However, in practice, the relationships between variables might be nonstationary and vary geographically (Matthews, Yang 2012, p. 152).

Locally linear regression, introduced to the economic context by McMillen (1996), is a relatively recent modelling technique for spatial data analysis. The technique was extended and relabelled geographically weighted regression by Fotheringham, Charlton and Brunsdon (1996, 1997, 2002). Unlike global regression models, where a single coefficient is estimated for each explanatory variable, GWR allows local variations (over space) in those coefficients to be estimated. This method generates a separate regression equation for each observation, that can be expressed as follows (Brunsdon, Fotheringham, Charlton 1996, p. 284):

$$y_i = \beta_0(u_i, v_i) + \sum \beta_k(u_i, v_i) x_{ik} + \varepsilon_i, \tag{2}$$

where: (ui, vi) - coordinate location of i.

The estimator for this model takes a form of (Charlton, Fotheringham 2009, pp. 5-6):

$$\boldsymbol{\beta}' = [\mathbf{X}^T \mathbf{W}(u_i, v_i) \mathbf{X}]^{-1} \mathbf{X}^T \mathbf{W}(u_i, v_i) \mathbf{Y}, \tag{3}$$

where: $\mathbf{W}(u_i, v_i)$ - square matrix of weights relative to the position of (u_i, vi) in the study area, XTW(ui, vi)X -geographically weighted variance-covariance matrix (the estimation requires its inverse to be obtained), Y - vector of the values of the dependent variable.

The W (ui, vi) matrix contains the geographical weights in its leading diagonal and 0 in its off-diagonal elements.

$$\mathbf{W}(u_i,v_i)=\begin{bmatrix}\mathbf{w}_1(u_i,v_i) & 0 & 0\\ 0 & \dots & 0\\ 0 & 0 & \mathbf{w}_n(u_i,v_i)\end{bmatrix} \tag{4}$$

Each equation is calibrated using a different weighting of the observations contained in the data set. The assumption is that observations nearby one another have a greater influence on one another's parameter estimates than observations farther apart. The weight assigned to each observation is based on a distance decay function centred on observation i (Mennis 2006, p. 172).

GWR provides great richness of results that are usually presented on maps. As a minimum, this technigue produces parameter estimates and their standard errors at the regression points. If the regression points are the same as the sample points, GWR also produce fitted values for the dependent variable, residuals and standardised residuals. Some implementations output local goodness-of-fit measures and influence statistics based on the hat matrix (Charlton, Fotheringham 2009, p. 9). Mapping GWR results facilitates interpretation based on spatial context and known characteristics of the study area (Mathews, Yang 2012, p. 155).

GWR is a tool which is more and more often used in demographic as well as socio-economic research. In particular, in analyses related to healthcare – incidence of diseases and access to medical services (Nakaya, Fotheringham, Brunsdon, Charlton M. 2005; Young, Gotway 2010; Comber, Brunsdon, Radburn 2011, Kisiala 2013), environmental protection (Foody 2003; Gilbert, Chakraborty 2011), real estate market (Yu, Wei, Wu 2007, Cellmer R. 2013), population density (Lo 2008), poverty (Benson, Chamberlin, Rhinehart 2005; Partridge, Rickman 2007) and migrations (Byrne, Pezić 2004; Jensen, Deller 2007; Jivraj, Brown, Finney 2013).

In their article entitled Spatial Modeling of the Migration of Older People with a Focus on Amenities, T. Jansen and S. Deller (2007) presented results of an analysis of the impact of selected factors, including amenities connected with natural resources of regions (i.e. access to forests, lakes) and climate conditions, on the migration of the elderly in the United States. The study was conducted on statistical data concerning 3,072 spatial units (districts) in the years 1995-2000. The results of the analysis suggest that older migrants cannot be treated as a homogenous group and amenities (e.g. warmer weather, natural and historical attractions) have a significant impact on explaining their migration decisions. The amenity measures used in that study had distinctly different implications for the dependent variable in individual localities. The GWR estimates were more efficient than those of the OLS for all presented models.

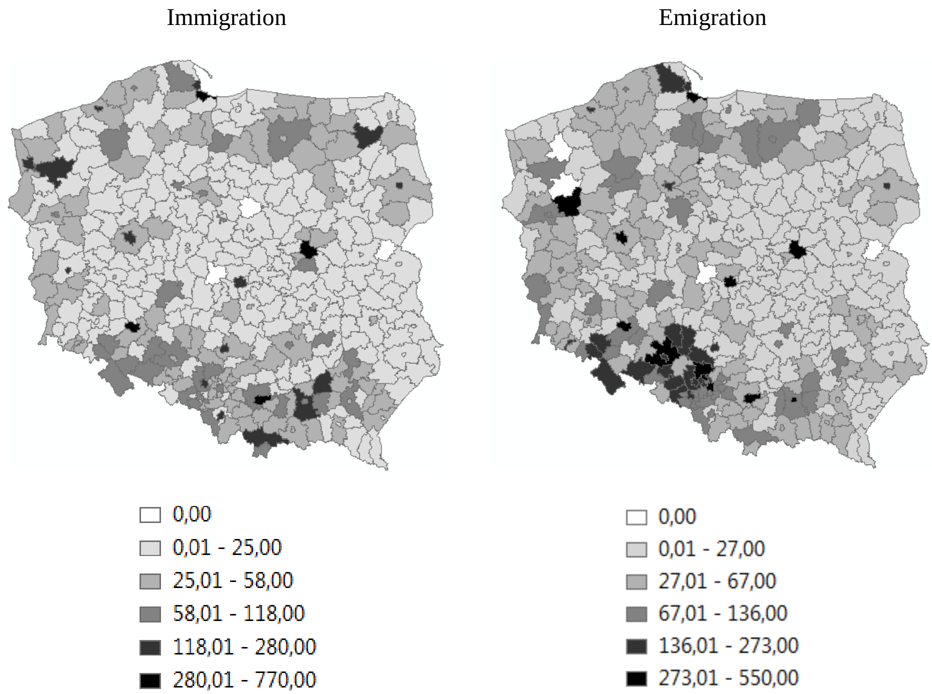
In the article entitled Modelling Internal Migration Drivers with Geographically Weighted Regression, G. Byrne and A. Pezić (2004) described results of the spatial analysis of internal migration in Australia having a major impact on a rise in the country's population. The GWR method was used to estimate the effect of factors such as unemployment, house prices and other socio-economic variables on the internal migration measure. The study was carried out on statistical data concerning 203 statistical local areas in Victoria, with attention restricted to the regional centre of Bendigo in Victoria. The results presented in the article support the view that the effects of internal migration drivers are spatially non-stationary. That is why local model estimates were more efficient than those of the global model. Spatial variations in the model parameters where presented on maps and characterized in detail. The results showed inter alia that high migrant flows are concentrated immediately South, West and North-West of Bendigo, flows from the remainder of Victoria are relatively small.

4. Preliminary Analysis of Statistical Data

The foreign migration (emigration and immigration) in Poland was analysed from the spatial perspective based on statistical database built on the basis of information available at the Local Data Bank of the Central Statistical Office, published on the official website of the office. Statistical data was collected for 379 poviats of Poland in 2012. Major determinants of creating the database were both, reasons pertaining to the subject matter and availability of data at the time of carrying out the study. Regrettably, not all variables needed for the analysis of foreign migration are available for specific poviats (e.g. GDP).

Figure 3 presents immigration and emigration volumes for specific poviats in 2012. Maps clearly show that the greatest number of people who left Poland to permanently reside abroad was reported in the South of the country – in the Śląskie, Dolnośląskie and Opolskie voivodships as well as in Gdańsk, Warsaw and Łódź. On the other hand, no emigration was noted in the Łobeski, Łosicki, Poddębicki and Choszczeński poviats. It can be observed that the population residing in the Western and Northern part of the country is more mobile. The highest number of immigrants settled in big cities, i.e. Warsaw, Wrocław, Cracow, Gdańsk, Gdynia and Białystok. No immigration was reported in the Łosicki, Poddębicki and Sierpecki poviats. Foreigners most willing settle in the Southern and Northern borderlands of the country, less often in Central and Eastern Poland.

Figure 3. Emigration and immigration in Polish poviats in 2012



Source: own work in ArcMap, based on statistical data of the Central Statistical Office.

Both variables are characterized by high spatial variability and positive global autocorrelation. In 2012 Moran's statistic for immigration was 0.08, while it was 0.26 for emigration (received results are statistically significant). The local statistic for immigration indicates that low values of the variable group in poviats situated in the Kujawsko-Pomorskie, Mazowieckie and Lubelskie voivodships. As for emigration, the local statistic indicates that low values of the variable group in poviats located in the Mazowieckie and Lubelskie voivodships, and high values – in the Opolskie voivodship.

5. Modelling of Foreign Migration in Poland

The analysis of foreign migration in Poland in 2012 was conducted using two econometric models describing immigration and emigration. The first step in examining the impact of selected socio-economic variables on the values of dependent variables was to create global models. Final models, whose parameters were estimated using the OLS method, had the following form:

$$\widehat{IM} = -20{,}0619 + 0{,}1460LOP + 0{,}0004LM + 0{,}1976M + 0{,}0051DB$$

(-5,5) (5,8) (14,0) (2,2) (3,3)

$$\widehat{EM} = -319{,}7660 - 0{,}3844M - 4{,}4567PS + 4{,}2662K + 0{,}7811IM - 4{,}7531DG$$

(-3,3) (-2,6) (-4,7) (4,5) (17,9) (-3,4)

where: DB – poviats' budgetary incomes per capita in 2012, DG – number of individuals carrying out business activity per 100 of the working age population in 2012, EM – number of emigrants in 2012, IM – number of immigrants in 2012, K – number of women per 100 men in 2012, LM – number of the population in 2012, LOP – number of job offers in 2012, M – dwellings completed per 10 thousand of the population in 2012, PS – share of the working age population using social assistance in the place of residence in the total number of population of that age in 2012.

All model coefficients are statistically significant. The determination coefficient for the immigration model is 73%, while it is 59.9% for the emigration model. It should be emphasized that there is a spatial autocorrelation of residuals in both models.

As the next step, parameters of local models were estimated having the same forms as for global models. Local regression coefficients descriptive statistics for the immigration model are presented in Table 1. It can be observed that median values for specific parameters are similar to results received for the global model.

Table 1. Local regression coefficients descriptive statistics – immigration model

Variable	Minimum	Median	Maximum
Constant	-74,1470	-24,1943	20,1350
LOP	-0,8078	0,0362	0,8355
LM	-0,0001	0,0004	0,0013
M	-0,8840	0,0652	1,5511
DBM	-0,0109	0,0056	0,0309

Source: own work.

Table 2 shows statistics used to compare the global and local models describing immigration in 2012. All measures indicate the markedly better fit of the local model to empirical data – both the determination coefficient, which is higher in the GWR model, and the Akaike Information Criterion, whose value is lower in the local model.

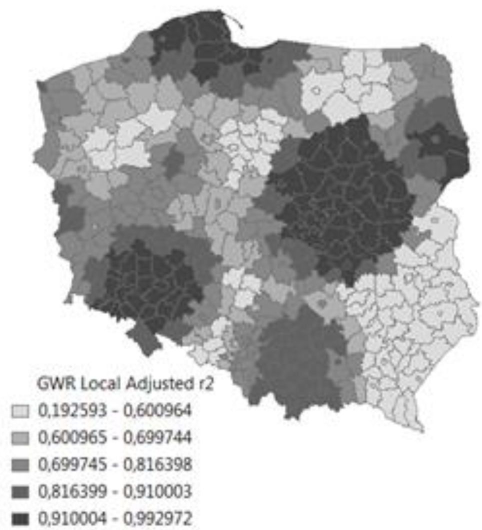
Table 2. Diagnostic statistic for global and local models

	Global model - OLS	**Local model - GWR**
Akaike Information Criterion	3805.003	3572.464
Coefficient of Determination (R^2)	0.732	0.913
Adjusted R^2	0.73	0.89
Residual Sum of Squares	492370.15	160072.37

Source: own work.

Figure 4 presents local values of the determination coefficient. It can be observed that the model is characterized by insufficient fit to data, particularly for poviats located in the South-Eastern part of the country, whereas the fit is best for the Mazowieckie, Dolnośląskie and Pomorskie vovodships.

Figure 4. Local adjusted R^2 in immigration model

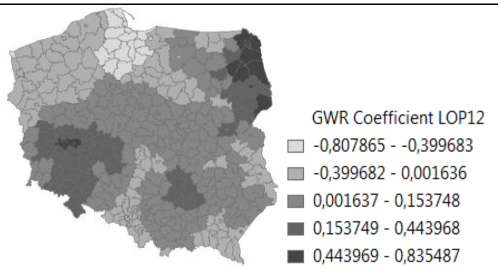
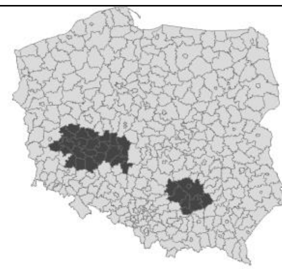
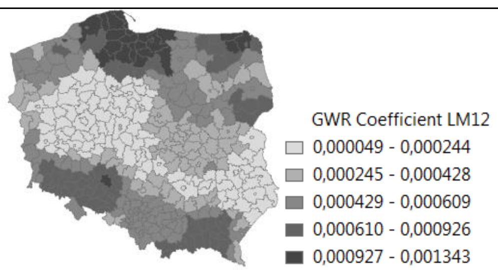
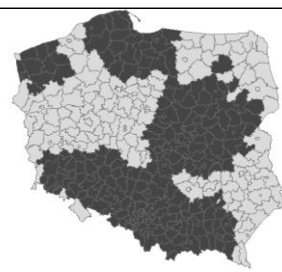
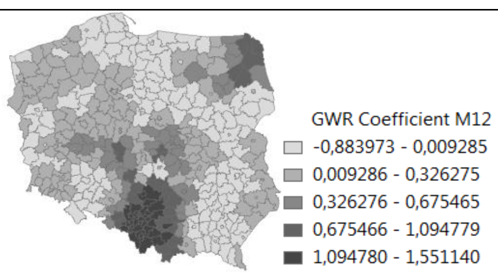


Source: own work in ArcMap.

Table 3 shows local values of coefficients and t-statistics calculated for the immigration model. Maps concerning the significance of parameters clearly show that they are not statistically significant for each locality. All other factors being constant, a rise in the population significantly affects a rise in the number of immigrants for the highest number of poviats. That means that foreigners most willingly settle in big cities where it is easier to find work and dwelling, access commercial and cultural facilities. An increase in the number of job offers affects a growth in the number of migrants in poviats situated in the

Wielkopolskie, Świętokrzyskie and Dolnośląskie voivodships. Economic migration is currently the predominant form of population mobility. Thus, people move to areas where it is easy to find employment. A rise in the number of dwellings significantly affected an increase in immigration mainly in poviats located in the Śląskie and Małopolskie voivodships. In turn, an increase in poviats' budgetary incomes had an impact on a growth in the number of immigrants in poviats situated in the Pomorskie, Zachodniopomorskie, Wielkopolskie and Małopolskie voivodships. That variable is among the measures of local development. If budgetary incomes go up, economic conditions in a poviat improve. That amounts to economic growth, making the area more attractive to potential immigrants.

Table 3. Local values of parameters and t-statistics in the immigration model

<table>
<tr><th>Variable</th><th>Coefficients</th><th>t – Statistics</th></tr>
<tr><td>LOP</td><td>
</td><td></td></tr>
<tr><td>LM</td><td>
</td><td></td></tr>
<tr><td>M</td><td>
</td><td></td></tr>
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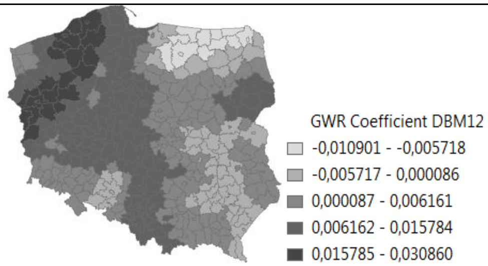
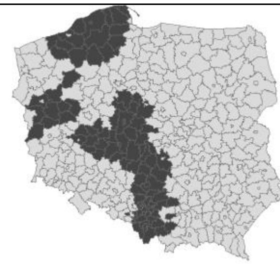
DB		
		not significant significant

Source: own work in ArcMap.

The last step of the study was to estimate parameters of the GWR model describing emigration. Local regression coefficients descriptive statistics for the emigration model are presented in Table 4.

Table 4. Local regression coefficients descriptive statistics – emigration model

Variable	Minimum	Median	Maximum
Constant	-1468,500	-381,611	67,152
M	-1,389	4,490	16,975
PS	-11,748	-2,487	2,115
K	-0,480	-0,257	0,631
IM	-0,053	0,714	1,398
DG	-23,050	-3,958	6,608

Source: own work.

In turn, Table 5 shows statistics used to compare the global and local models describing emigration in 2012. Similarly to the first (immigration) model, all measures indicate the markedly better fit of the local model to empirical data – both the coefficient of determination, which is higher in the GWR model, and the Akaike Information Criterion, whose value is lower in the local model.

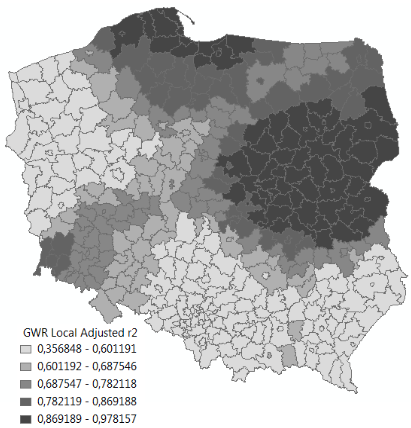
Table 5. Diagnostic statistic for global and local models

	Global model - OLS	Local model - GWR
Akaike Information Criterion	4057,71	3971,561
Coefficient of Determination (R^2)	0,599	0,763
Adjusted R^2	0,595	0,726
Residual Sum of Squares	953868,99	566681,15

Source: own work.

Figure 5 presents local values of the determination coefficient. It can be observed that the model is characterized by insufficient fit to data, particularly for poviats located in the Southern and Western parts of the country, whereas the fit is best for the Mazowieckie, Podlaskie and Pomorskie voivodships.

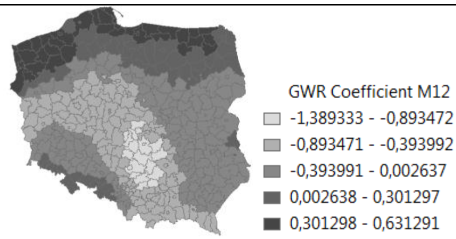
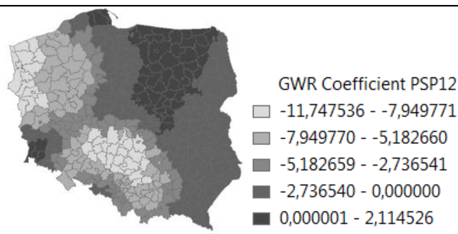
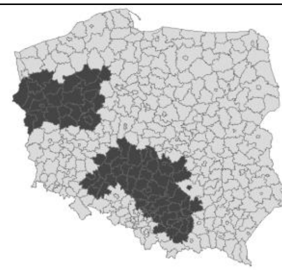
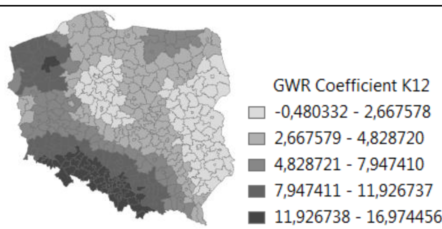
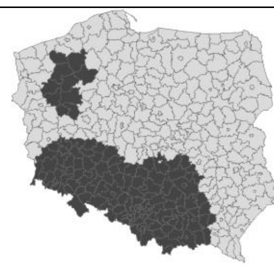
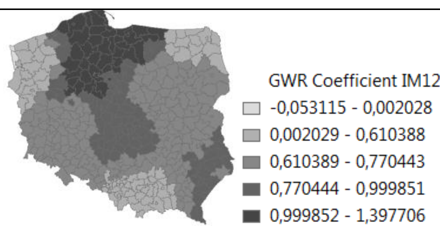
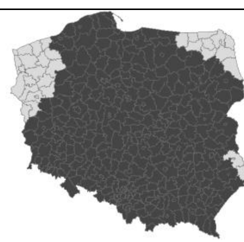
Figure 5. Local adjusted R^2 in emigration model

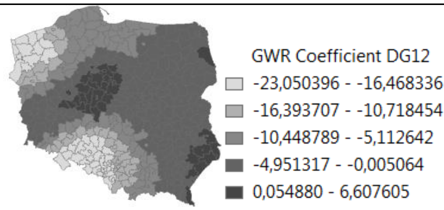
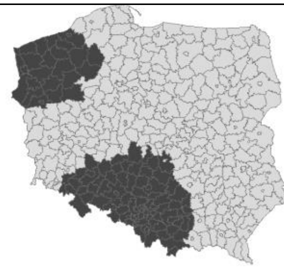


Source: own work in ArcMap.

Table 6 shows local values of coefficients and t-statistics calculated for the emigration model. Also in that case, parameters are not significant for every locality. It can also be observed that variables affect one another with varying intensity. All other factors being constant, a rise in the number of dwellings in poviats located in the Łódzkie, Świętokrzyskie and Śląskie voivodships led to a significant decrease in emigration. As compared to other European countries, housing situation in Poland is very poor. Inability to rent or buy a flat often affects a decision to emigrate, especially among young people. In Southern Poland (Śląskie, Dolnośląskie, Małopolskie voivodships) a rise in the number of women (per 100 men) results in an increase in emigration. That means that it is not only economic factors that determine a decision to leave the country. According to the femininity ratio published by the Central Statistical Office, there are currently 109 women per 100 men in Poland. It is possible that this situation makes women decide to emigrate more often than men. A rise in the working age of population using social assistance significantly affects a fall in emigration in poviats located in the Western and South-Western part of the country. That leads to a conclusion that improvement in social policy could contribute to stopping people's emigration from Poland. A variable that significantly affected emigration in almost the whole country in 2012 was immigration. Immigrants coming especially from countries of the Eastern Bloc tend to take up jobs with lower salaries, thus causing job offers to be "sucked out" of the labour market. In Western and South-Western Poland, a rise in the number of individuals carrying out economic activity significantly affects a drop in emigration. That variable is among measures of economic development; it generates jobs. Hence, it is negatively correlated with emigration.

Table 6. Local values of parameters and *t*-statistics in the emigration model

<table>
<tr><th>Variable</th><th>Coefficients</th><th>t – Statistics</th></tr>
<tr><td>M</td><td>
</td><td></td></tr>
<tr><td>PS</td><td>
</td><td></td></tr>
<tr><td>K</td><td>
</td><td></td></tr>
<tr><td>IM</td><td>
</td><td></td></tr>
</table>

<table>
<tr>
<td>DG</td>
<td>
</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>not significant
significant</td>
</tr>
</table>

Source: own work in ArcMap.

5. Conclusion

The opening of borders between European countries ensured free movement of people in Europe. Reasons for emigration are often very complex, with the predominance of economic ones associated with looking for jobs offering fair remuneration. It should, however, be emphasized that various social aspects of migration are increasingly mentioned, too.

Based on the conducted it can be stated that the net migration in Poland was negative in 2012, i.e. emigration exceeded immigration. A positive net migration was observed only in 133 poviats, mainly in big cities, i.e. Warsaw, Cracow, Wrocław, Szczecin and Gdynia.

The analysis of foreign migrations in Poland in 2012 was conducted using two econometric models describing immigration and emigration. An attempt was made to specify socio-economic variables that may fundamentally affect the studied phenomenon and estimate parameters of the geographically weighted regression model. The method proved to be an extremely useful instrument of spatial data analysis. Local models were characterized by a considerably better fit to empirical data than global ones. They allowed to evaluate the significance of parameters of models for specific spatial units. Based on the received results, it was inferred that emigration of people from Poland is affected not only by economic but also social aspects, i.e. desire to find a partner and buy or rent a flat. It was also observed that improvement in social policy related to benefits could limit the movement of population abroad. In turn, immigrants tend to settle in big and highly developed poviats offering better chances of finding employment.

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Streszczenie

PRZESTRZENNA ANALIZA MIGRACJI ZAGRANICZNYCH W POLSCE W 2012 R. Z WYKORZYSTANIEM GEOGRAFICZNIE WAŻONEJ REGRESJI

Migracje ludności w znaczącym stopniu wpływają na kształtowanie się liczby ludności w krajach. Z tego względu zagadnienia związane przyczynami, skutkami i kierunkami ruchów ludności są coraz częstszym przedmiotem politycznych i akademickich dyskusji.

Celem artykułu jest analiza przestrzennego rozmieszczenia poziomu emigracji i imigracji w Polsce w 2012 r. Metody geograficznych systemów informacyjnych wykorzystano w celu wizualizacji i wstępnej (statystycznej) analizy danych. Następnie podjęto próbę specyfikacji zmiennych ekonomiczno-społecznych, które mogą mieć zasadniczy wpływ na kształtowanie się badanego zjawiska oraz estymacji parametrów modelu geograficznie ważonej regresji (GWR). Metoda ta umożliwia identyfikację zmienności współczynników regresji w przestrzenni geograficznej.

Słowa kluczowe*: emigracja, imigracja, analiza przestrzenna, GWR, GIS*

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EDYTA ŁASZKIEWICZ*, GUANPENG DONG, RICHARD HARRIS*****

The Effect Of Omitted Spatial Effects And Social Dependence In The Modelling Of Household Expenditure For Fruits And Vegetables

Abstract

As is well known, ignoring spatial heterogeneity leads to biased parameter estimates, while omitting the spatial lag of a dependent variable results in biasness and inconsistency (Anselin, 1988). However, the common approach to analysing households' expenditures is to ignore the potential spatial effects and social dependence. In light of this, the aim of this paper is to examine the consequences of omitting the spatial effects as well as social dependence in households' expenditures.

We use the Household Budget Survey microdata for the year 2011 from which we took households' expenditures for fruits and vegetables. The effect of ignoring spatial effects and/or social dependence is analysed using four different models obtained by imposing restrictions on the core parameters of the hierarchical spatial autoregressive model (HSAR). Finally, we estimate the HSAR model to demonstrate the existence of spatial effects and social dependence.

We find the omitted elements of the external environment affect negatively the estimates for other spatial (social) effect parameters. Especially, we notice the overestimation of the random effect variance when the social dependence is omitted and the overestimation of the social interaction effect when the spatial heterogeneity is ignored.

***Keywords**: social interaction, consumption behavior, spatial multilevel model*

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1. Introduction

In the spatial econometrics literature, the negative consequences of ignoring the presence spatial autocorrelation and/or spatial heterogeneity are well known (see e.g. Anselin 1988; Anselin and Griffith 1988). Various methods have been proposed to handle the spatial effects, including: spatial econometric model (e.g. Anselin 1988; LeSage and Pace, 2010), spatially switching regression (Anselin 1990), random coefficient models (Longford 1993) and geographically weighted regression (Fotheringham et al. 2003), among others. Recently, growing attention has been given to the synergy between multilevel and spatial econometric modelling to achieve a spatial multilevel approach (Corrado and Fingleton 2012; Baltagi et al. 2014; Dong and Harris 2014).

Despite above, in many areas of microeconomics studies there is still little interest in the spatial and multilevel approach. One such field is the analysis of consumption behaviour in which the exploration of the hierarchical structure of the microdata as well as the spatial or social dependence has rarely been seen. A few exceptions are the work of Ball et al. (2006) and of Giskes et al. (2006). However, the role of spatial context or the impact of others' decisions on a person's own shopping choices is rarely considered. Because consumers are not separated from each other and live in places that differ by, e.g. the accessibility of the products, so we can expect there to be spatial and social dependence. More general we can say that consumption behaviours are affected by the external environment.

The aim of this paper is to examine the consequences of ignoring the spatial effects and/or social dependence in the analysis of consumption behaviour. We use the microdata from the Household Budget Survey of Poland to explore how misleading conclusions might be drawn when the external environment of the consumption choices is omitted. The hierarchical spatial autoregressive (HSAR) model is applied as well as four additional, misspecified models for comparison. The conclusions from our work are potentially useful as they increase awareness about the merits of using a spatial multilevel approach.

The rest of the paper is organized as follows. In the next section we presented the HSAR model and its variations that result from imposing restrictions on the parameters of the HSAR model. The Bayesian MCMC method of estimation is also described briefly. In section three the characteristics of the data we used is provided. After this, the empirical results for the expenditures model is presented in section four. Finally, the conclusion follows.

2. Method

Our data has the multilevel structure with households at the individual level and statistical survey points at the community level. Due to this, we use the hierarchical spatial autoregressive model (HSAR) proposed by Dong and Harris (2014). The general formula of the model is as follows:

$$\begin{aligned}
&\mathbf{Y} = \rho\mathbf{WY} + \boldsymbol{\beta}\mathbf{X} + \boldsymbol{\Delta}\boldsymbol{\theta} + \boldsymbol{\varepsilon},\\
&\boldsymbol{\theta} = \lambda\mathbf{M}\boldsymbol{\theta} + \boldsymbol{\mu},\\
&\varepsilon \sim N(0, \mathbf{I}_N\sigma_\varepsilon^2),\\
&\mu \sim N(0, \mathbf{I}_J\sigma_\mu^2),
\end{aligned} \tag{1}$$

where Y is an N×1 vector of a dependent variable. In this research, the dependent variable was specified as the logarithm of the monthly households' expenditures for fruits and vegetables. The N=37 375 is the total number of households in the sample. The X is an N×K matrix of control variables (with constant), while β is a K×1 vector of coefficients to estimate. The N×1 vector of error terms was assigned as ε, while μ is J×1 vector of random effects for the communities. The total number of communities is J=1 551. We assumed that both the error term and random effects are normally distributed with variance σε2 and σμ2, respectively. The estimated parameter of the social interaction between households is ρ and λ is the estimated parameter of the spatial interaction between communities. The N×J block-diagonal design matrix Δ is as follows:

$$\boldsymbol{\Delta} = \begin{bmatrix} \mathbf{l}_1 & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{l}_2 & \cdots & \mathbf{0} \\ \cdots & \cdots & \cdots & \cdots \\ \mathbf{0} & \mathbf{0} & \cdots & \mathbf{l}_J \end{bmatrix}, \tag{2}$$

where: 0 is nj×1 vector of zeroes and nj is the number of households located in the community j.

In the N×N social interaction matrix W we specified the structure of the relationships between each pair of households. It can be written as:

$$\mathbf{W} = \begin{bmatrix} \mathbf{W}_1 & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{W}_2 & \cdots & \mathbf{0} \\ \cdots & \cdots & \cdots & \cdots \\ \mathbf{0} & \mathbf{0} & \cdots & \mathbf{W}_J \end{bmatrix}. \quad (3)$$

The elements, w_{ij} of each submatrices $\mathbf{W}_j$ were calculated as the inverse exponential function of the time differences in months. The time means the month when the household declared the expenditures for fruits and vegetables. The result of applying above weights is the assignation of the higher weights (the stronger relationship between households) for those pairs which declared the expenditures in the same or adjacent time. The greater the difference between the declaration about the expenditures, the weaker is the potential influence in a pair of the households. It can be written as:

$$w_{ij} = \begin{cases} 1/\exp(\Delta t)^2 \text{ if } t_i \geq t_{i'} \wedge i \neq i' \\ 0 \text{ if } t_i < t_{i'} \vee i = i' \end{cases}, \quad (4)$$

where: $\Delta t=t_i-t_{i'}$, $t_i=1,\ldots,12$ denotes the time when household i declared expenditures for fruits and vegetables.

Moreover, the $J\times J$ block-diagonal spatial matrix $\mathbf{M}$ was specified to capture the spatial interactions between communities located in the same voivodship (region). It is as follows:

$$\mathbf{M} = \begin{bmatrix} \mathbf{M}_1 & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{M}_2 & \cdots & \mathbf{0} \\ \cdots & \cdots & \cdots & \cdots \\ \mathbf{0} & \mathbf{0} & \cdots & \mathbf{M}_R \end{bmatrix}. \quad (5)$$

The elements of each from the $R=16$ submatrices $\mathbf{M}_r$ were specified as a binary function with the value one if two communities are located in the same voivodship, or zero otherwise. Only the group-wise spatial dependence was applicable to spatial relationships between communities as only the information about the community location in the voivodship was known. Using the notation in Corrado and Fingleton (2012) it can be expressed as:

$$\mathbf{M}_r = \frac{1}{n_r}\left(\mathbf{l}_{nr}\mathbf{l}_{nr}^{'}\right), \tag{6}$$

where: $\boldsymbol{l}_{nr}$ is a $n_r \times 1$ column vector of ones**.** Both **W** and **M** matrices were row-standardized.

Additional models, which are used in the research, are obtained by imposing the restrictions on the HSAR parameters. Four different scenarios were studied: lack of both spatial effects and social dependence, omitted spatial effects, lack of social dependence and lack of spatial dependence. They were achieved as follows:

- λ=0 and σ_μ^2=0, which is the equivalent of a standard spatial autoregressive model. In this model we ignore the spatial effects. It means there is no spatial interaction between communities (λ=0) as well as no differences between communities in the level of expenditures for fruits and vegetables (σ_μ^2=0);
- ρ=0 and λ=0, which gives a standard multilevel model in which we ignore the potential social interactions between households (ρ=0) and spatial interactions between communities (λ=0);
- ρ=0, which means we allow for the spatial effects but omit the potential social dependence. In this model we concentrate only on the heterogeneity and dependence effects at the community level, and
- λ=0, which is the equivalent of a model with social interactions at the individual level and spatial heterogeneity at the community level. This model was achieved by combing the spatial autoregressive model and multilevel model. Although it allows for the inequalities of the expenditures at the community level, the potential spatial interactions among communities is not modelled.

The Bayesian Markov Chain Monte Carlo (MCMC) method was used to estimate the HSAR and four additional models. According to Dong and Harris (2014) the prior distributions for each parameter in the HSAR model are specified as follows:

$$\begin{aligned} &P(\boldsymbol{\beta}) \sim N(\mathbf{M}_0, \mathbf{T}_0), \\ &P(\rho) \sim U(1/\upsilon_{\rho\min}, 1), P(\lambda) \sim U(1/\upsilon_{\lambda\min}, 1), \\ &P(\sigma_\varepsilon^2) \sim IG(c_0, d_0), P(\sigma_\mu^2) \sim IG(a_0, b_0), \end{aligned} \tag{7}$$

where: $\mathbf{M}_0$ is the $K\times1$ vector of means, $\mathbf{T}_0$ is the variance matrix, υ_{min} is the minimum eigenvalue of the weight matrix, *IG* is the inverse gamma distribution with the shape parameter a_0 or c_0 and scale parameter b_0 or d_0, *N* is the normal distribution and *U* is the uniform distribution.

The full posterior conditional distributions for each model parameter are derived based on the likelihood function for the HSAR model and the prior distributions (see Dong and Harris, 2014). Hence, the conditional posterior distributions were:

$$P(\boldsymbol{\beta} \mid \mathbf{Y}, \rho, \lambda, \boldsymbol{\theta}, \sigma_\varepsilon^2, \sigma_\mu^2) \sim N(\mathbf{M}_\beta, \boldsymbol{\Sigma}_\beta), \tag{8}$$

with:

$$\begin{aligned} \boldsymbol{\Sigma}_\beta &= \left[\left(\sigma_\varepsilon^2\right)^{-1}\mathbf{X}'\mathbf{X} + \mathbf{T}_0^{-1}\right]^{-1}, \\ \mathbf{M}_\beta &= \boldsymbol{\Sigma}_\beta\left[\left(\sigma_\varepsilon^2\right)^{-1}\mathbf{X}'\left(\mathbf{AY} - \boldsymbol{\Delta\theta}\right) + \mathbf{T}_0^{-1}\mathbf{M}_0\right] \end{aligned} \tag{9}$$

$$P(\boldsymbol{\theta} \mid \mathbf{Y}, \rho, \lambda, \boldsymbol{\beta}, \sigma_\varepsilon^2, \sigma_\mu^2) \sim N(\mathrm{M}_{\boldsymbol{\theta}}, \Sigma_{\boldsymbol{\theta}}), \tag{10}$$

with:

$$\begin{aligned} \Sigma_\theta &= \left[\left(\sigma_\varepsilon^2\right)^{-1}\Delta'\Delta + \left(\sigma_\mu^2\right)^{-1}\mathbf{B}'\mathbf{B}\right]^{-1}, \\ \mathrm{M}_{\boldsymbol{\theta}} &= \Sigma_\theta\left[\left(\sigma_\varepsilon^2\right)^{-1}\Delta'\left(\mathbf{AY} - \mathbf{X}\boldsymbol{\beta}\right)\right] \end{aligned} \tag{11}$$

$$P(\sigma_\mu^2 \mid \mathbf{Y}, \rho, \lambda, \boldsymbol{\beta}, \boldsymbol{\theta}, \sigma_\varepsilon^2) \sim IV(a_\mu, b_\mu), \tag{12}$$

with:

$$\begin{aligned} a_\mu &= J/2 + a_0, \\ b_\mu &= \boldsymbol{\theta}'\mathbf{B}'\mathbf{B}\boldsymbol{\theta}/2 + b_0. \end{aligned} \tag{13}$$

$$P(\sigma_\varepsilon^2 \mid \mathbf{Y}, \rho, \lambda, \boldsymbol{\beta}, \boldsymbol{\theta}, \sigma_\mu^2) \sim IV(c_\varepsilon, d_\varepsilon), \tag{14}$$

with:

$$\begin{aligned} c_\varepsilon &= N/2 + c_0, \\ d_\varepsilon &= 0{,}5\times\left(\mathbf{AY} - \mathbf{X}\boldsymbol{\beta} - \boldsymbol{\Delta\theta}\right)'\left(\mathbf{AY} - \mathbf{X}\boldsymbol{\beta} - \boldsymbol{\Delta\theta}\right) + d_0. \end{aligned} \tag{15}$$

where: $\mathbf{A} = \mathbf{I}_N - \rho\mathbf{W}$ and $\mathbf{B} = \mathbf{I}_J - \lambda\mathbf{M}$. The Gibbs sampler was employed to draw the samples for parameters.

Because the posterior distributions for ρ and λ do not fit standard recognizable density distributions, the inverse sampling method was used to update the social and spatial interaction parameters. More specifically, in each iteration after the numerical integration of Log *f*(ρ) over (1/ $\upsilon_{\rho min}$,1) and Log *f*(λ) over (1/ $\upsilon_{\lambda min}$, 1), the cumulative distribution of ρ and λ were calculated. Then, the inverse sampling approach was employed to draw values of both parameters. The Log *f*(ρ) and Log *f*(λ) in the HSAR model are as follows:

- For the social interaction parameter ρ:

$$\text{Log } f(\rho) = \log\left|\mathbf{I}_N - \rho\mathbf{W}\right| + S(\rho)'S(\rho)/2\sigma_\varepsilon^2 + m, \quad (16)$$

with:

$$\begin{aligned} S(\rho) &= (\mathbf{Y} - \mathbf{X}\boldsymbol{\beta}_0) - \rho(\mathbf{WY} - \mathbf{X}\boldsymbol{\beta}_d) - (\boldsymbol{\Delta\theta} - \mathbf{X}\boldsymbol{\beta}_u), \\ \boldsymbol{\beta}_0 &= (\mathbf{X'X})^{-1}\mathbf{X'Y}, \\ \boldsymbol{\beta}_d &= (\mathbf{X'X})^{-1}\mathbf{X'WY}, \\ \boldsymbol{\beta}_u &= (\mathbf{X'X})^{-1}\mathbf{X'}\boldsymbol{\Delta\theta}. \end{aligned} \quad (17)$$

- For the spatial interaction parameter λ:

$$\text{Log } f(\lambda) = \log\left|\mathbf{I}_J - \lambda\mathbf{M}\right| + \boldsymbol{\theta}'\mathbf{B}'\mathbf{B}\boldsymbol{\theta}/2\sigma_\mu^2, \quad (18)$$

where: *m* is a constant.

For further discussion about the MCMC algorithm for implementing the HSAR model see Dong and Harris (2014). The MCMC samplers for the HSAR model and other four models were coded using the R language. The convergence of the MCMC samplers was diagnosed using the CODA package in R Cran (Plummer et al. 2006). The inferences were based on one MCMC chain that each consist of 10 000 iterations with a burn-in period of 5000 for each model. For all models, diffuse or quite non-informative priors are used for parameters while the initial values are drawn randomly from their prior distributions.

3. Database and descriptive statistics for dependent and control variables

The microdata used in this study comes from the 2011 Polish Household Budget Survey. It is the largest and most representative survey for household expenditure in Poland, conducted by the Central Statistical Office (GUS). The full sample consists of N=37 375 households as each of these households declared non-zero expenditures for fruits and vegetables. The community level was defined as the area survey point and consists of J=1 551 spatial units. The category of fruits and vegetables expenditures was separated with consistency with the Classification of Expenditures on Consumer Goods and Services (GUS, 2011, pp. 256-257).

In 2011, the average monthly households' expenditure for fruits and vegetables was 118 PLN which accounted for almost 18% of the total food expenditures. The distribution of the expenditures was characterized by the high, positive kurtosis (11,69) and skewness (1,97). Hence, to approximate the normal distribution, the log transformation was used for the value of households' expenditures and the transformed variable was taken as the dependent variable in our models.

As for the control variables, we used those which represent households' socio-economic status and personal attributes of the reference person. The household profile was characterized by the number of persons in the household (h_size) and by the type of the household. The type was classified into four dummy-variables: couples with children (couple_ch), couples without a child (couple_nch), singles (single) and others (reference category). The mean values of expenditures from each type of household were found to be significantly different from each other. The highest expenditures for fruits and vegetables were noticed for couples with children (138 PLN). To control for the household size effect we repeated the analysis using the value of expenditures per capita but the differences between types of household was still significant. The logarithm of the households' monthly available income was used to capture the economic conditions of the household. To avoid potential multicollinearity only two personal attributes were taken into account: sex (1 if male) and age (as a continuous variable) of the reference person.

In addition, we found the value of expenditures for fruits and vegetables varies between the hierarchies of locality. As shown in Table 1, median expenditure per capita was significantly higher in the biggest Polish cities with the population over 500 thousand (ref.category) than in the other cities and rural areas in 2011. The median decreases with the city size and the lowest was noticed for villages (34,26 PLN). Hence, we added five dummy-variables to represent the hierarchy of locality: cities with 200-499 thous. inhabitants (cities_1), towns with population 100-199 thous. (cities_2), towns with 20-99 thous. (cities_3), towns with less than 20 thous. inhabitants (cities_4) and rural areas (rural).

Table 1. Descriptive statistics for households' expenditures for class of locality

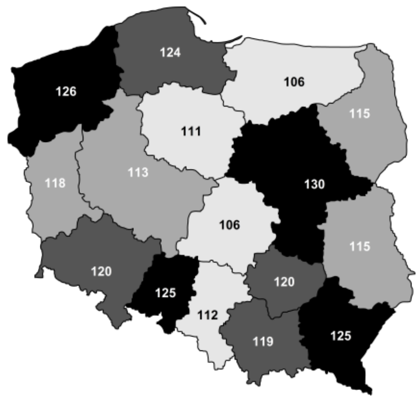
class of locality	expenditures per capita*		
	median	quantile 25%	quantile 75%
ref. category	50,28	32,22	77,33
cities_1	43,65	28,36	66,60
cities_2	41,31	26,17	63,50
cities_3	40,76	25,99	63,69
cities_4	38,58	24,41	59,36
rural	34,26	22,66	52,40

* In Polish zloty.

Source: authors' own.

An additional source of the place-related variation in expenditure was due to the household location in the voivodship (see Figure 1). According to the results from the Wilks' lambda test for equality of 16 group means (conducted on both the value of expenditures and the value per capita), there are regional differences in the level of fruits and vegetables consumption. The regional differences were captured by allowing for the inter-regional dependence in the spatial matrix **M**. Another way to incorporate it would be adding the regional fixed effects.

Figure 1. Average household expenditures for fruits and vegetables in Polish voivodships



Source: authors' own.

4. Empirical results

We started our analyses from the results for the OLS and SAR models (Section 4.1) to check for the existence of the social dependence. Then we estimated the MLM model (Section 4.2) to find the spatial heterogeneity at the community level. In the next two subsections, the results for the HSAR models with $\rho=0$ (Section 4.3) and $\lambda=0$ (Section 4.4) were analyzed, while in the last one (Section 4.5) the results for the HSAR model without restrictions on parameters were presented.

4.1. Omitted spatial heterogeneity and dependence

In the OLS model, 22% of the total variance of households' expenditures for fruits and vegetables were explained[1]. The signs of the estimated parameters for all control variables were as expected (see Table 2). We computed Moran's I test for the OLS residuals using the social interaction matrix W. The Moran's I statistic was equal to 0,1 and significant at the 0,01 level. Because the OLS residuals are correlated, we should incorporate the social dependence into our model to avoid the misspecification.

Following the sequence of models outlined above, we first estimated a SAR model, which is the equivalent of the HSAR model with the following restrictions on parameters: λ=0, σμ2=0. It means we allow only for the social dependence effect while leave unexamined spatial heterogeneity and dependence effects at the community level. The results are shown in Table 2. The estimated error variance was lower than in the OLS model by about 2,4%. The 95% credible intervals for the σε2 in the SAR model do not contain the value of σε2 from the OLS. This might suggest an overestimation of the error variance in the OLS.

Table 2. Estimation results for fruits and vegetables expenditures using OLS and SAR models

variable	OLS		SAR			
	coef.	std.err.	posterior mean	std. error	2,5%	97,5%
intercept	3,261	0,036	2,506	0,044	2,476	2,592
log_income	0,123	0,004	0,118	0,004	0,116	0,125
h_size	0,107	0,004	0,107	0,004	0,105	0,114
age	0,004	0,000	0,004	0,000	0,004	0,004
sex	-0,025	0,007	-0,027	0,007	-0,032	-0,013
couple_ch	0,066	0,011	0,068	0,011	0,060	0,088
couple_nch	0,038	0,010	0,040	0,010	0,034	0,059
single	-0,411	0,013	-0,406	0,013	-0,415	-0,381
cities_1	-0,079	0,014	-0,071	0,014	-0,081	-0,045
cities_2	-0,110	0,015	-0,104	0,015	-0,113	-0,075
cities_3	-0,103	0,012	-0,098	0,012	-0,106	-0,075
cities_4	-0,141	0,013	-0,132	0,013	-0,141	-0,107
rural	-0,129	0,011	-0,132	0,011	-0,139	-0,111
ρ			0,174	0,007	0,170	0,187
σ_ε^2	0,379		0,370	0,003	0,368	0,375

Source: Own calculations in R Cran.

[1] It is typical to obtain the low value of the R-squared for the models based on the micro data (see e.g. Cameron, Trivedi, 2005, p. 7).

We find that the estimate for the social interaction (ρ) is positive and significant. It suggests that interpersonal relationships affect the level of household consumption of fruits and vegetables. Although we allowed for the social dependence, the estimation for the control variables did not change significantly.

4.2. Omitted social and spatial dependence

Next we estimated the multilevel model (MLM) obtained by adding the restrictions on the HSAR parameters: λ=0 and ρ=0. In the MLM model only spatial heterogeneity was allowed and we assumed no social or spatial dependence. The spatial heterogeneity was defined as the difference in the households' expenditures between communities. The estimation results are presented in Table 3.

Table 3. Estimation results for fruits and vegetables expenditures using a MLM model

variable	posterior mean	std. error	2,5%	97,5%
intercept	3,320	0,034	3,316	3,413
log_income	0,113	0,004	0,110	0,120
h_size	0,108	0,004	0,106	0,116
age	0,004	0,000	0,004	0,004
sex	-0,029	0,007	-0,033	-0,015
couple_ch	0,067	0,011	0,060	0,088
couple_nch	0,043	0,010	0,036	0,061
single	-0,410	0,013	-0,418	-0,385
cities_1	-0,081	0,002	-0,096	-0,036
cities_2	-0,112	0,024	-0,129	-0,065
cities_3	-0,105	0,019	-0,120	-0,067
cities_4	-0,143	0,021	-0,158	-0,102
rural	-0,134	0,017	-0,146	-0,101
σ_μ^2	0,028	0,002	0,027	0,031
σ_ε^2	0,351	0,003	0,350	0,356

Source: Own calculations in R Cran.

We notice the significant decrease of the error variance in comparison to the OLS model (7,4%) as well as the SAR (5,1%). The random effect variance is significant, which suggests the existence of spatial heterogeneity at the community level. Such variation of the households' expenditures was 8,0% of the total variance. Additionally, and as with to the results from the SAR model we find no significant changes in terms of estimation for the control variables.

Again, only the estimate for the intercept seems to be affected by the omitted social dependence (in the SAR model) and spatial heterogeneity (in the MLM model). Although the estimation results for fruits and vegetables expenditures from the MLM model look very convincing, we should check for the social dependence, which is suggested from the estimation results in the SAR model.

We checked if the residuals from the MLM model are correlated using Moran's I test. The statistic was insignificant proving lack of the social autocorrelation in the residuals. The same procedure was applied to test the presence of spatial dependence in the community random effects. We separated the estimated random effects as $\mathbf{\Delta\theta}$ and used the matrix **W** to conduct the Moran's I test. The results support the hypothesis of the existence of the social dependence. The value of the Moran's I statistic was equal to 0,1 with a 0,01 significance level. However, as long as the structure of the interaction in matrix **W** is based on the inter-community relations such result for $\mathbf{\Delta\theta}$ seems to be obvious.

We also test the estimated random effects for the presence of spatial dependence using matrix **M**. The Moran I statistic was equal to 0,6 and significant at the 0,01 level. It suggests that the assumption that the community specific effects are independent has been violated. We expected in this case that the estimated random effect variance was affected not only by the omitted social dependence but also by the additional spatial dependence. It might result in an overestimation of the variance but further research is necessary to answer the question about how the spatial and social dependence affect the estimates for the random effect variance.

4.3. Omitted social dependence

In the next step, we estimate the model with both spatial heterogeneity and spatial dependence at the community level but without social dependence between households. The model we achieve was the equivalent of the HSAR model with $\rho=0$. We estimated it because we are interested in the nature of model misspecification connected with the omitted social interactions.

The estimation results for the HSAR model without social dependence are presented in Table 4. Again, the estimates for the control variables were similar in terms of statistical inference, when compared to those obtained from the OLS, SAR and MLM models. The value of the estimated intercept was not significantly different from that obtained by using the MLM model but was significantly higher than that in the OLS and SAR models.

The estimate for the parameter λ (the measure of spatial dependence) was significant, which suggests the necessity of incorporating it in the model. As long as we allowed for the spatial interactions between communities the estimated value of the random effect variance decreased significantly (about 10,7%). The results obtained support the observation that the random effect variance is overestimated when the spatial dependence is omitted. Despite this, in the HSAR model with ρ=0 we might expect that both the random effects, the error variance and the estimate for λ are biased because of the existence of social dependence among households.

Table 4. Estimation results for fruits and vegetables expenditures using HSAR model with ρ=0

variable	posterior mean	std. error	2,5%	97,5%
intercept	3,331	0,042	3,303	3,414
log_income	0,113	0,004	0,110	0,120
h_size	0,109	0,004	0,106	0,116
age	0,004	0,000	0,004	0,004
sex	-0,027	0,008	-0,033	-0,013
couple_ch	0,067	0,011	0,060	0,088
couple_nch	0,043	0,010	0,036	0,062
single	-0,411	0,013	-0,420	-0,385
cities_1	-0,073	0,025	-0,090	-0,025
cities_2	-0,089	0,027	-0,106	-0,037
cities_3	-0,091	0,020	-0,106	-0,053
cities_4	-0,137	0,021	-0,151	-0,094
rural	-0,123	0,018	-0,137	-0,091
λ	0,709	0,056	0,674	0,808
σ_μ^2	0,025	0,002	0,023	0,028
σ_ε^2	0,386	0,003	0,384	0,392

Source: Own calculations in R Cran.

4.4. Omitted spatial dependence

In contrast to the previous model we allow now for the social dependence as well as spatial heterogeneity but omitted the spatial dependence at the community level. We are used the HSAR model with the restriction of λ=0. The estimation result was presented in Table 5.

Again, the estimated parameters for the control variable are stable. That might suggest that as long as the control variables are not correlated with the spatial dependence or heterogeneity and social dependence parameters, there are negligible negative effects on the estimated parameters of such variables due to the omitted ρ, λ or σμ2.

As with the previous models, the omitted spatial or social dependence affected mostly the estimates for the random effect variance. We notice that when we allowed for the social dependence the estimated variance of the random effects decreased significantly (by 46,4% in comparison with the MLM model). Also, we observe a significant decrease of the estimates for ρ, when the spatial heterogeneity was captured (by 15,5% compared to the SAR model). It suggests that the omitted spatial heterogeneity results in an overestimation of the social interaction parameter in the SAR model.

Table 5. Estimation results for fruits and vegetables expenditures using HSAR model with λ=0

variable	posterior mean	std. error	2,5%	97,5%
intercept	2,668	0,048	2,636	2,762
log_income	0,113	0,004	0,111	0,121
h_size	0,108	0,004	0,106	0,115
age	0,004	0,000	0,004	0,004
sex	-0,029	0,007	-0,033	-0,014
couple_ch	0,068	0,011	0,061	0,089
couple_nch	0,043	0,010	0,036	0,062
single	-0,408	0,013	-0,417	-0,383
cities_1	-0,075	0,019	-0,089	-0,037
cities_2	-0,107	0,021	-0,121	-0,065
cities_3	-0,101	0,016	-0,113	-0,070
cities_4	-0,136	0,018	-0,149	-0,102
rural	-0,137	0,015	-0,146	-0,108
ρ	0,147	0,001	0,142	0,160
σ_μ^2	0,015	0,001	0,013	0,018
σ_ε^2	0,375	0,003	0,373	0,381

Source: Own calculations in R Cran.

The overestimation was also found for the random effect variance when the social or spatial dependence is not taken into account. The estimated error variance was not significantly different from that in the SAR model but was higher than that from the MLM model (by 6,8%) and lower than that from the HSAR model with ρ=0 (by 2,8%).

4.5. Social dependence, spatial dependence and heterogeneity in the HSAR model

As the final as full model we estimate the HSAR model allowing for both spatial effects and social dependence. According to the estimation results (in Table 6) all of the mentioned above effects were found to be significant for the fruits and vegetables expenditures. The estimate for the error variance from the HSAR model is lower than that from previous models, except for the MLM model. The estimated ρ parameter decreases sharply in comparison with both the SAR and HSAR model with λ=0. This suggests that both models might overestimate the value of ρ. The overestimation can be due to and reflective of the omitted spatial heterogeneity and/or dependence. In contrast, the estimates for the λ parameter do not change significantly in comparison with the HSAR model with ρ=0. It implies that ignoring the social dependence does not significantly affect the estimates for the spatial dependence.

Table 6. Estimation results for fruits and vegetables expenditures using HSAR model

variable	posterior mean	std. error	2,5%	97,5%
intercept	2,980	0,051	2,945	3,082
log_income	0,112	0,004	0,110	0,119
h_size	0,109	0,004	0,106	0,116
age	0,004	0,000	0,004	0,004
sex	-0,028	0,007	-0,032	-0,014
couple_ch	0,067	0,011	0,060	0,088
couple_nch	0,044	0,010	0,036	0,061
single	-0,410	0,013	-0,419	-0,385
cities_1	-0,069	0,023	-0,085	-0,023
cities_2	-0,087	0,024	-0,103	-0,039
cities_3	-0,089	0,018	-0,101	-0,054
cities_4	-0,133	0,020	-0,146	-0,093
rural	-0,127	0,017	-0,138	-0,094
ρ	0,077	0,008	0,072	0,092
λ	0,717	0,055	0,679	0,815
σ_μ^2	0,020	0,001	0,019	0,022
σ_ε^2	0,352	0,003	0,351	0,358

Source: Own calculations in R Cran.

Finally, we find the significant decreased of the estimates for the random effect variance (compare with the results from the Table 3 and 4). The estimate for the random effect variance in this model decreased by 40% and 25%, respectively when compared to the MLM model and the HSAR model with $\rho=0$. The decline suggests the importance of accounting for the spatial and/or social dependence effect when analysing households' expenditure attributes.

5. Conclusions

In this paper we discussed the consequence of ignoring the spatial effects and/or social dependence in the analysis of households' expenditures for fruits and vegetables. We illustrated that the omitted elements of external environment negatively affect the estimates for some important parameters and as a result misleading conclusions might be drawn. According to the results for the households' expenditures, the omitted spatial effects affect the estimation results – for example an overestimation of the social interaction parameter. Analogously, in the presence of social dependence, omitted interpersonal relationships affect results in the overestimation of the random effect variance. The negative consequences are also noticeable in the case of lack of the spatial dependence at the higher level. If the communities are spatially correlated but this correlation is ignored in the model, both the estimates for the parameter of social dependence and spatial heterogeneity are affected. The estimated parameters for the control variables (except the intercept) were found as the least susceptible for the omitted spatial effects and/or social dependence.

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Streszczenie

SKUTKI POMINIĘCIA EFEKTÓW PRZESTRZENNYCH I SPOŁECZNYCH ZALEŻNOŚCI W MODELU WYDATKÓW GOSPODARSTW DOMOWYCH NA OWOCE I WARZYWA

Pominięcie przestrzennej heterogeniczności w modelu ekonometrycznym skutkuje błędnym oszacowaniem parametrów, zaś brak uwzględnienia opóźnionej przestrzennie zmiennej zależnej skutkuje obciążeniem i brakiem zgodności estymatora (Anselin 1988). Mimo tego w analizach wydatków gospodarstw domowych efekty przestrzenne oraz interakcje społeczne są najczęściej pomijane.

W pracy skoncentrowano się na skutkach pominięcia efektów przestrzennych i ww. interakcji. W badaniu wykorzystano mikrodane pochodzące z Badania Budżetów Gospodarstw Domowych (2011 r.), dotyczące wydatków na owoce i warzywa. Skutki pominięcia efektów *przestrzennych i/lub interakcji międzyludzkich zweryfikowano wykorzystując hierarchiczny model autoregresji przestrzennej (HSAR) oraz cztery modele uzyskane poprzez nałożenie restrykcji na parametry modelu HSAR.*

Uzyskane wyniki potwierdziły negatywny wpływ pominięcia składowych środowiska zewnętrznego na oszacowania wybranych parametrów. Zaobserwowano przeszacowanie parametru odzwierciedlającego skalę przestrzennej heterogeniczności w sytuacji pominięcia interakcji międzyludzkich oraz przeszacowanie parametru tychże interakcji w sytuacji pominięcia przestrzennej niejednorodności zjawiska.

Słowa kluczowe: *interakcje społeczne, zachowania konsumpcyjne, przestrzenne modele wielopoziomowe*

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EMILIA MODRANKA*, JADWIGA SUCHECKA**

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.

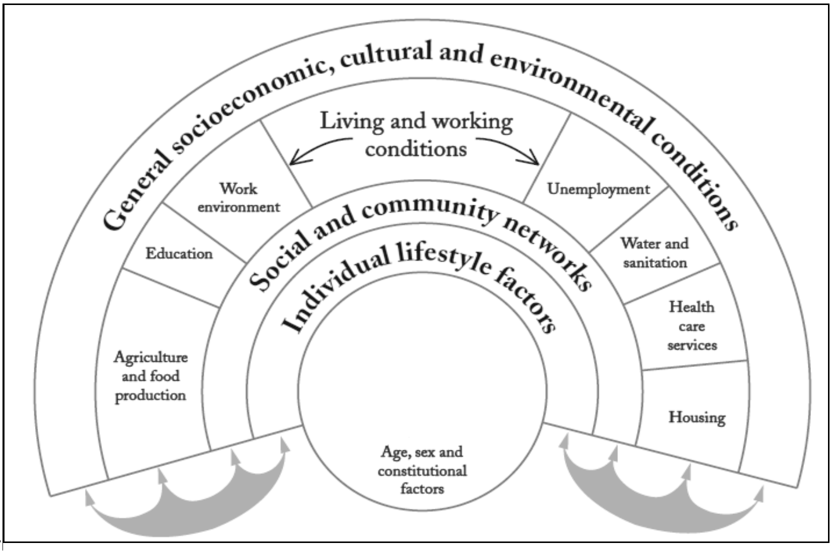
The health care organization is a category which consists of the quantity, quality, arrangement, nature and relationships of people and resources in the provision of health care. It includes medical practice, nursing, hospitals, nursing homes, medical drugs, public and community health care services, 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



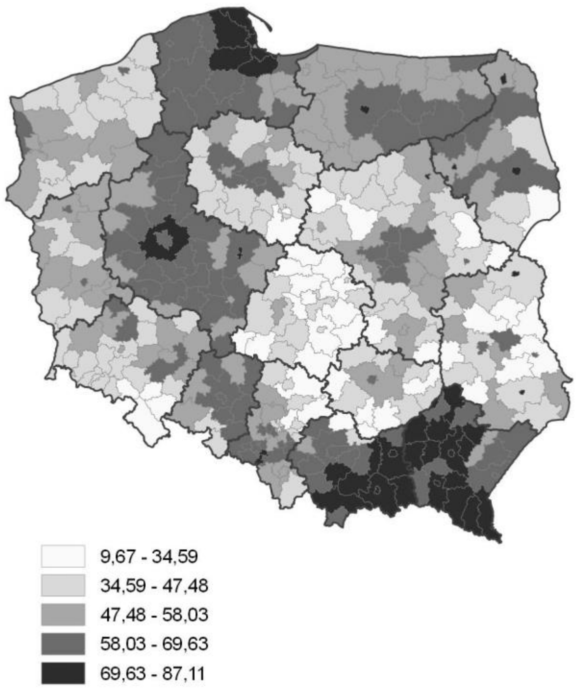
Source: Dahlgren, Whitehead 2007, p. 20.

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, ζ - 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)

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

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:

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

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*

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ALICJA OLEJNIK*

An Empirical Study Of Productivity Growth In EU28 - Spatial Panel Analysis[1]

Abstract

This paper investigates the spatial process of productivity growth in the European Union on the foundations of the theory of New Economic Geography. The proposed model is based on the study of NUTS 2 regions and takes into consideration a spatial weights matrix in order to better describe the structure of spatial dependence between EU regions. Furthermore, our paper attempts to investigate the applicability of some new approaches to spatial modelling including parameterization of the spatial weights matrix. Our study presents an application of the spatial panel model with fixed effects to Fingleton's theoretical framework. We suggest that the applied approach constitutes an innovation to spatial econometric studies providing additional information hence, a deeper analysis of the investigated problem.

***Keywords**: spatial panel model, spatial econometrics, productivity growth*

1. Introduction

New Economic Geography (NEG) presented mainly in Fujita, Krugman and Venables (1999) has significantly influenced the regional analysis of the concentration of economic activity, and in particular placed increasing returns

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processes in the mainstream of economics. However, the NEG theory is more a theoretical description of the real world than a ready formula for application. Nevertheless, recently the number of papers which take the new theory as a point of departure for their analysis is increasing (cf. Combes and Lafourcade 2001 and 2004, Combes and Overman 2003, Redding and Venables 2004, Fingleton 2005a, 2005b, 2006).

The aim of this paper is to analyse the spatial process of productivity growth in the European Union (EU) on the foundations of the theory of New Economic Geography. The presented model is based on the study of NUTS 2 regions and applies Fingleton's model of productivity growth which, in turn, is essentially founded on the NEG theory. Our work also takes into consideration a spatial weights matrix in order to better describe the spatial structure of the dependencies among the EU regions. Additionally, we attempt to investigate the applicability ,in the context of our study, of a new approach for describing the spatial structure, namely the parameterization of the spatial weights matrix.

This paper is structured as follows. Section 2 introduces the general idea of the spatial models and, in particular, inverse distance parameterized spatial weights matrix. In Section 3 we present the theoretical background for our study. Section 4 describes data used in the empirical analysis. Empirical results and discussion are presented in Section 5. Finally, Section 6 provides a summary and some concluding remarks.

2. Inverse distance parameterized spatial weights matrix

Spatial data usually violates the assumption made by ordinary regression methods that observations are independent of each other. This has strong methodological implications for the quality of estimates and therefore, for the conclusions drawn from such models. Alternative methods for dealing with relationships involving spatial data are the econometric tools delivered by spatial econometrics.

A classic spatial autoregressive SAR model for cross-sectional observations with normal disturbances takes the following form:

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

where **y** (N×1) represents an N×1 vector consisting of one observation of the dependent variable for every unit in the spatial sample i=1,… , N. Matrix **X** (N×K) denotes observations on K exogenous variables. Typically, matrix **W** is a given *a priori* spatial weights matrix which represents the neighbourhood structure of the spatial locations. Typically, the elements of **W** ($N \times N$) are ones if locations i and j are close to each other and all others (in particular the diagonal elements) are zeroes.

One of the most often criticized aspects of using spatial econometric models is that the spatial weights matrix **W** is specified in advance instead of being estimated along with all the parameters in the model.

Researchers dealing with geographical units often adopt a *binary contiguity matrix* with elements equal to one if two regions share a common border and zero otherwise. The other popular spatial weights matrices based on the distance metrics are: *k-nearest neighbours matrix* with fixed number (k) of neighbours and the *inverse distance matrix*.

The common practice is to adopt one of the above spatial weights matrices. However, according to Vega and Elhorst (2013) even if there are theoretical reasons indicating that distance matters, it is usually not clear from the theory the degree to which the spatial dependence between units diminishes as distance increases. It seems to be reasonable to assume that theory should be the driving force that determines the specification of **W** (see e.g. Corrado and Fingleton (2012)). However, if there is no theoretical background, a good solution could be to compare the results using alternative functional forms of **W**.

Vega and Elhorst (2013) suggest that a remedy to that problem might be to estimate the *distance decay parameter*. Fischer et al. (2006) and Fischer et al. (2009) estimate the distance decay parameter using an exponential function in empirical applications investigating knowledge spillover. There have also been other studies that employ parameterized **W** (cf. Burridge and Gordon 1981, Kakamu 2005).

One of the most popular forms of the *inverse distance matrix* is that described by the *inverse distance power function* of the form:

$$w_{ij} = 1 / d_{ij}^{\gamma},$$

where w_{ij} are the elements of **W** matrix, d_{ij} denotes the distance between locations i and j, and γ is the *distance decay parameter*.

Let us consider the classic SLX model containing spatially lagged explanatory variables:

$$\mathbf{y} = \mathbf{X\beta} + \mathbf{WX\beta} + \mathbf{u}, \quad \mathbf{u} \sim \mathrm{N}(\mathbf{0}, \sigma^2\mathbf{I}). \tag{2}$$

If we adopt an inverse distance power matrix with γ as the distance decay parameter to the model (2), a Nonlinear Least Squares estimation method can be used for obtaining γ. That parameter along with the W matrix (defined above) can be used in any spatial econometric model such as the SAR model (eq. 1).

According to Vega and Elhorst (2013) the above specification of W provides more information about the nature of the interdependencies of the observations in the sample than conventional W. For instance, a low estimate of γ indicates that global rather than local spillover effect is present. Therefore, in such a case, the commonly used binary contiguity matrix would not accurately represent the spatial dependence structure.

3. The theoretical background

The theoretical background for the study is Bernard Fingleton's model (2001, 2004b) based on the New Economic Geography theory. By employing some simplifications he developed a spatial econometric model based on Verdoorn's Law (see Verdoorn 1949, Kaldor 1957) which ties up increase in productivity with increase in production. Verdoorn's law seems to be important in regional growth analysis as it embodies scale effects.

In Fingleton's model the rate of technical progress is assumed to be an indication of the presence of technological externalities. The technical progress rate is modelled by the means of a function of socio-economic conditions characteristic for a specific region. It is also assumed that the technical progress influences and is influenced by technical progress in neighbouring regions

As a result, the technical progress rate varies by region instead of being an unmodelled constant. It is assumed that the technical progress rate (λ) depends on the terms: Human capital (H), the Initial Level of Technology (G), the Spillover of Knowledge (S) and an autonomous rate which reflects 'learning by doing' which proceeds regardless of the other factors.

Another assumption is that fast/slow technical progress in neighbouring regions affects given region, which as a result, also experiences faster/slower technical progress. Furthermore, the rate of technical progress in distant regions will have less impact, so that the set of neighbouring regions is important due to the spatially impeded knowledge flows.

On the basis of the above assumptions Fingleton introduced the following specification:

$$\lambda = b_0 + \rho S + b_1 H + b_2 G + \varepsilon, \tag{3}$$

Let us notice that spillover of knowledge *S* is a spatially weighted rate of technical progress $S = \mathbf{W}\lambda$, where **W** is a spatial weights matrix defined in the previous section. Combining (3) and the above formula for *S* as determinants of the rate of growth of productivity, we obtain:

$$p = \lambda + b_3 q, \quad p = b_0 + \rho \mathbf{W}\lambda + b_1 H + b_2 G + b_3 q + \varepsilon. \qquad (4)$$

Further, applying some basic algebra we get:

$$\lambda = p - b_3 q, \quad \rho \mathbf{W}\lambda = \rho \mathbf{W} p - \rho \mathbf{W} b_3 q. \qquad (5)$$

Thus:

$$p = b_0 + \rho \mathbf{W} p + b_1 H + b_2 G + b_3 q - b_4 \mathbf{W} q + \varepsilon. \qquad (6)$$

This specification stipulates that $b_4 = \rho b_3$. This restriction makes the estimation somewhat problematic therefore, Fingleton (2004) suggest taking $b_4 = 0$. Alternatively, we can assume that the rate of technical progress depends not only on weighted average of technical progress in neighbouring regions but also on the weighted average of the rate of productivity growth:

$$\lambda = b_0 + \rho \mathbf{W} p + b_1 H + b_2 G + \varepsilon. \qquad (7)$$

Then, the rate of productivity growth can be described by the formula:

$$p = b_0 + \rho \mathbf{W} p + b_1 H + b_2 G + b_3 q + \varepsilon. \qquad (8)$$

In the above equation the parameter $b_3 = (\gamma - 1)/\gamma$ is called *Verdoorn's coefficient*. According to the assumptions of Verdoorn's law this coefficient should be around 0.5 (*cf.* Bernat 1996, Fingleton and McCombie 1998, Fingleton 2004b, Fingleton and López-Bazo 2006). Other empirical studies based on the framework given in (8) were carried out in Fingleton (2001, 2004b) and Olejnik (2012).

4. Data

The EU comprises 28 member states and 273 NUTS 2 regions. This study covers 261 regions of those excluding some French, Portuguese and Spanish regions due to their isolated position and Croatia because of the lack of comparable data. The eliminated regions are: Réunion (FR), Guadeloupe (FR), Martinique (FR), Guyane (FR), Região Autónoma dos Açores (PT), Região Autónoma da Madeira (PT), Ciudad Autónoma de Ceuta (ES), Ciudad Autónoma de Melilla (ES), Canarias (ES), Jadranska Hrvatska (HR) and Kontinentalna Hrvatska (HR).

All data used in the empirical part of this study are published by Eurostat[2] and refer to the years 2000-2011. Some missing information was interpolated from the past trends. Table 1 reports the essential description of the variables used in the study.

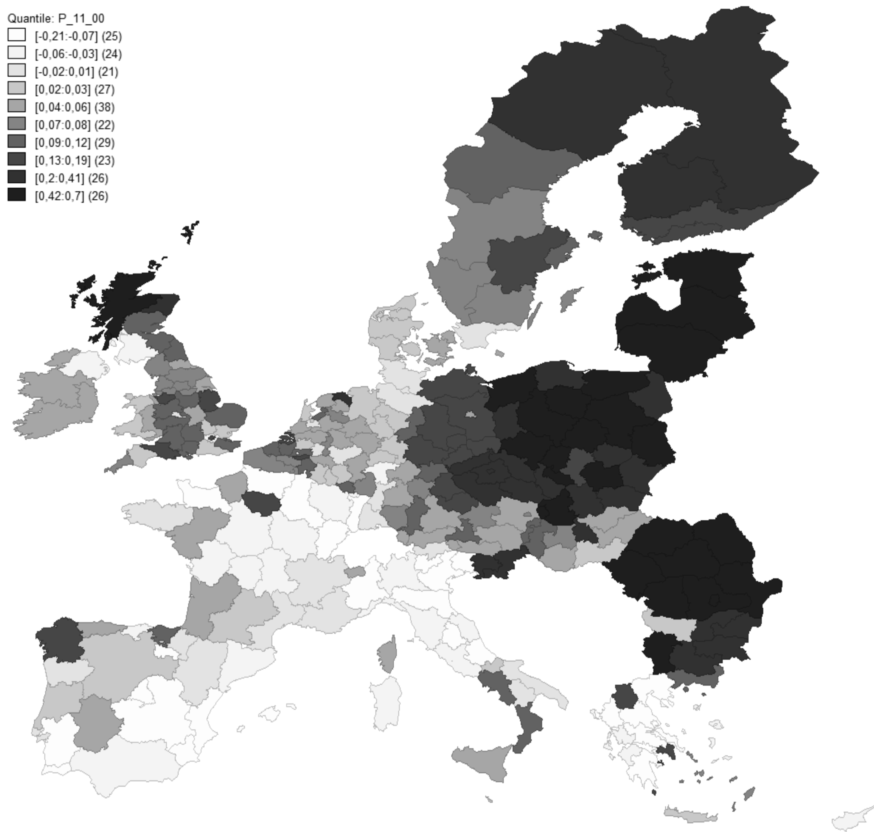
The regional productivity is explained by the quotient of regional GDP and the number of Economically Active Population (L). The productivity growth (p) for the years 2001-2011 is approximated by the exponential change of regional productivity in these years to regional productivity in the year 2000:

$$p = \ln\left[(GDP/L)_t^i / (GDP/L)_{2000}^i \right]. \tag{9}$$

The regional GDP is expressed in millions of Euro in constant prices (year 2000), where Economically Active Population is in thousands of people at the age of 15 or over. The map shown in Figure 1 visualizes the distribution of the productivity growth in the European regions in the year 2011 compared to 2000.

[2] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

Figure 1. Exponential change of productivity growth in EU NUTS 2 (year 2011/2000)

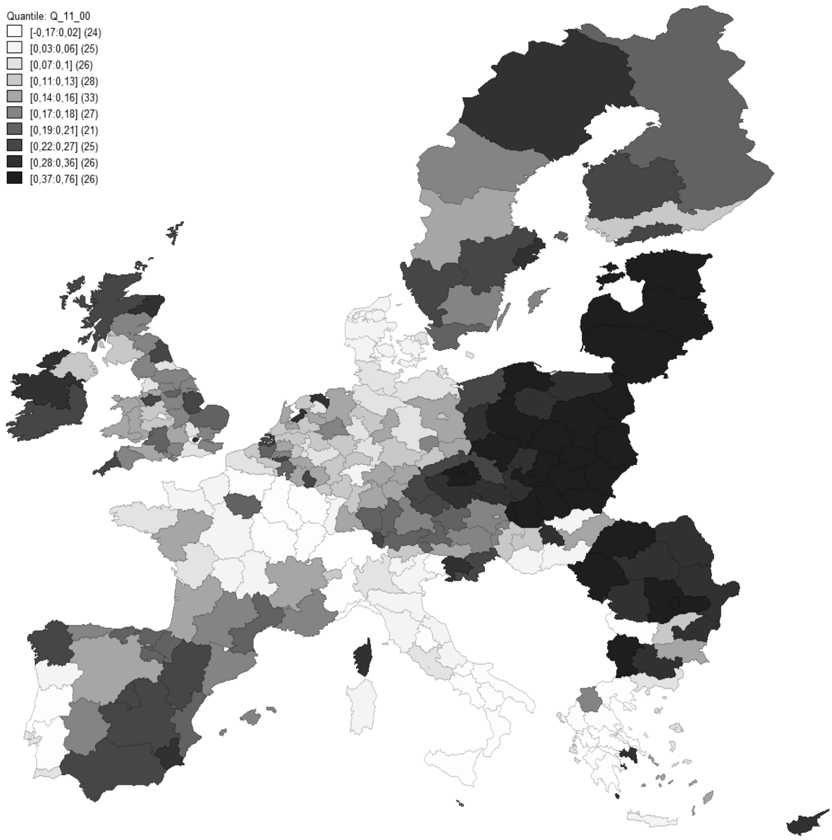


Source: author's own.

It can be seen in the figure that there is a clear tendency towards clustering regions with similar productivity growth (positive spatial autocorrelation).[3] The highest growth can be observed for regions of New European Union countries with the exception of some regions of Hungary and Bulgaria. Let us notice that Sud-Muntenia in Romania is the region with the highest productivity growth rate for years 2011/2000. Additionally within the old EU countries the highest productivity growth is observed for the Highlands and Islands region in UK. See Figures 2-4 for the visualization of the other variables.

[3] Regions in light colours are close to region in dark colours.

Figure 2. The exponential change of regional production in EU NUTS 2 (year 2011/2000)



Source: author's own.

The exponential change of regional production in years 2001-2011 to regional production in the year 2000 is approximated by:

$$q = \ln\left[(GDP_t^i / GDP_{2000}^i) \right]. \tag{10}$$

The Human capital (H) is defined by the Employment in Technology and Knowledge-intensive Sectors (T) as a percentage of Economically Active Population (L):

$$H = \ln\left[(\mathrm{T}/L)_t^i \right]. \tag{11}$$

The Initial Level of Technology (G_0) represents the technological gap between the *i*-th region and the technology leader of the whole economy of EU.

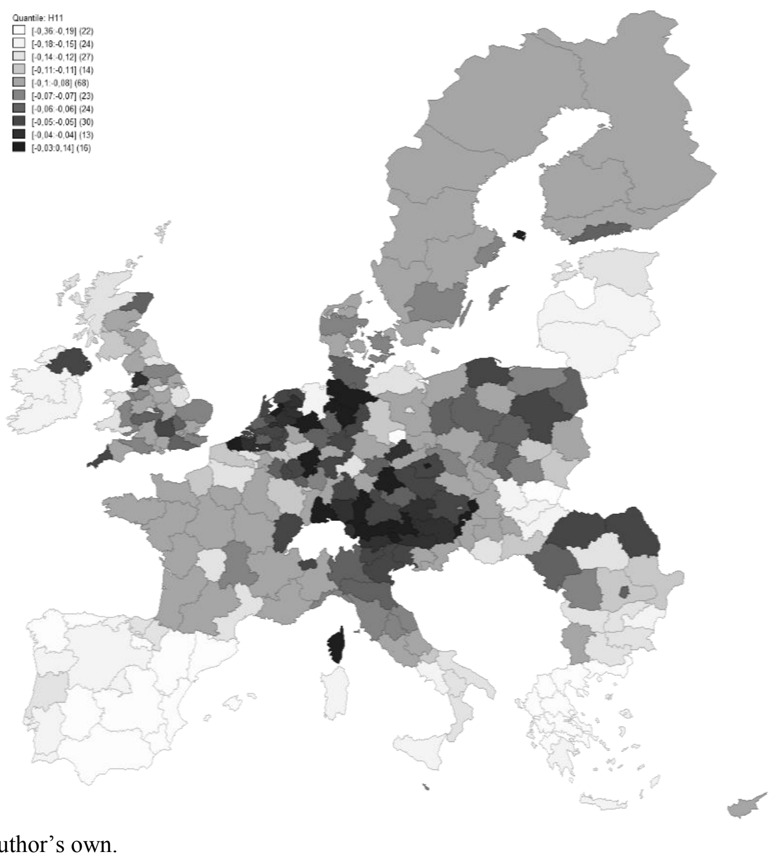
Therefore, the term G_0 is approximated by the economic distance from the technology leader at the beginning of the study which is year 2000:

$$G_0 = \ln[(GDP_{2000}^{\max} - GDP_{2000}^{i}) / GDP_{2000}^{\max}], \tag{12}$$

In this study the leading NUTS 2 region in terms of the highest *GDP per capita* level is Inner London.

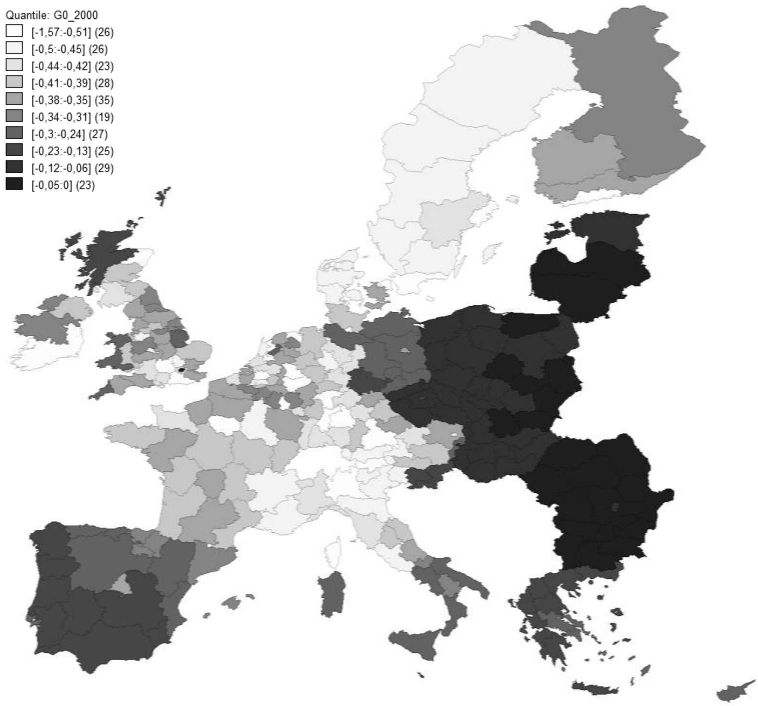
For the specification of the structure of the spatial effects we apply in turn: a row standardised spatial weights matrix **W** (261×261) of the three nearest neighbours (3nn), the contiguity and the inverse distance parameterized spatial weights matrix, described in Section 2.

Figure 3. Human Capital in EU NUTS 2 (year 2011)



Source: author's own.

Figure 4. Initial Level of Technology in EU NUTS 2 (year 2000)



Source: author's own.

Table 1. Variables description

Variable	*Mean*	*σ*	*Min*	*Max*
p	0.0825	0.1328	-0.2297	0.7043
q	0.1242	0.1121	-0.1678	0.7580
G_0	-0.3067	0.1929	-1.7906	-0.0163
H	-0.0891	0.0646	-1.0039	0.4760

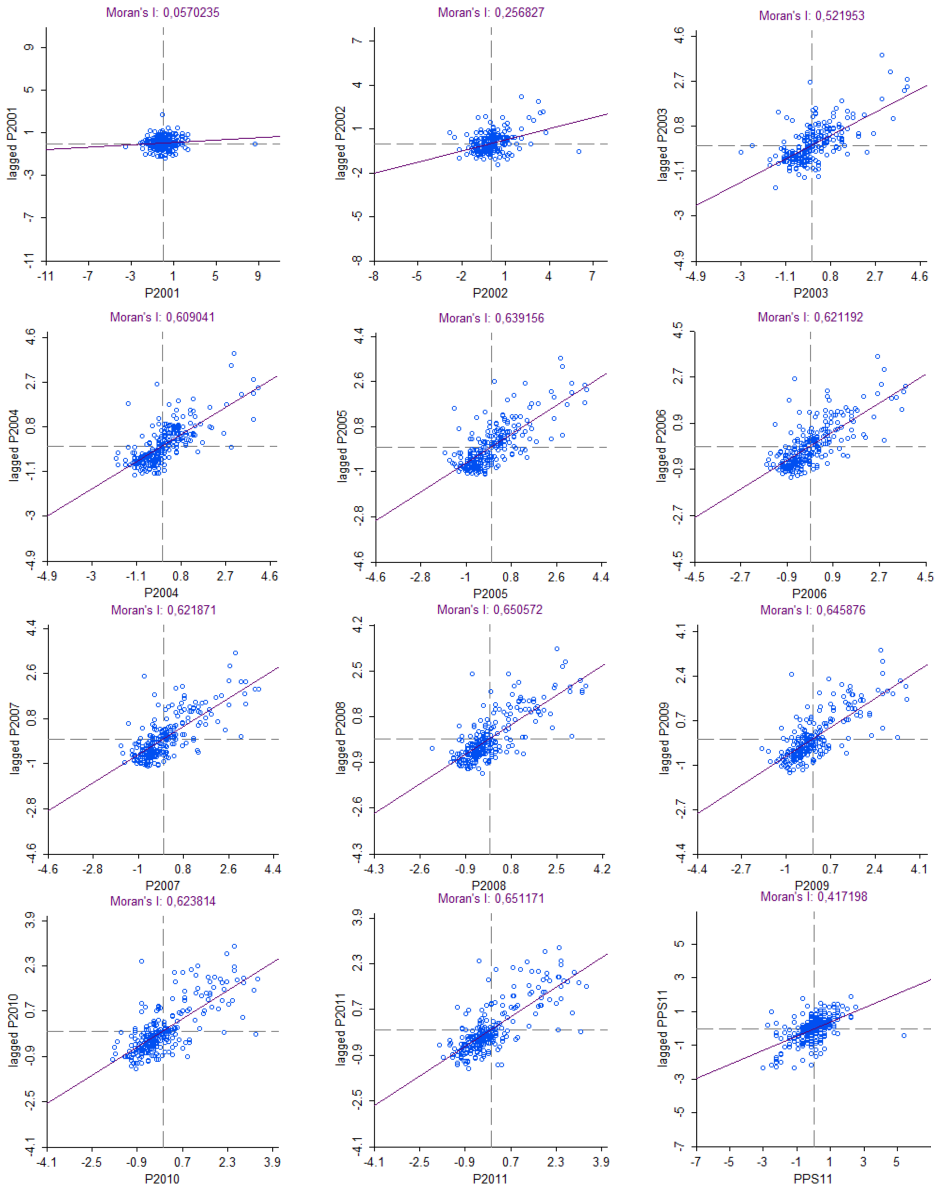
Source: Own calculations.

5. Empirical results and discussion

The starting point of the empirical part of the study was the analysis of spatial autocorrelation of the productivity growth. Figure 5 shows very strong spatial autocorrelation (Moran's I=0.6) over the time period of analysis. However, for 2001/2000 the spatial autocorrelation is weak yet significant at the 10% level.

The reported results are for 3nn spatial weights matrix, however, for contiguity spatial weights matrix the results were very similar. For comparison, spatial correlation for the year 2011 has also been added into the Figure 5.

Figure 5. Moran scatterplot for productivity growth for year 2001-2011(3nn matrix)



Source: Own calculations in GeoDa program.

The point of departure of our econometric analysis was the following spatial lag model:

$$\mathbf{p}=\alpha_0+\rho_1\mathbf{Wp}+\alpha_1\mathbf{H}+\alpha_2\mathbf{G_0}+\alpha_3\mathbf{q}+\boldsymbol{\varepsilon}, \quad (13)$$

where **p** represents the productivity growth for 2011/2000, **H** – Human Capital in 2011, $\mathbf{G}_0$ – Technology Gap in 2000 and **q** – growth of production in 2011 to 2000. The empirical results of the estimation are presented in Table 2. It can be seen that all the variables are highly significant at 1% level. The spatially lagged variable is also significant which suggests existence of the spatial spillover effect on the productivity growth.

Table 2. SAR results

Variable	*Coefficients*	*Std.*	*T-stat*
α_0	0.03	0.02	1.53
Wp	0.39	0.04	9.54
H	0.33	0.08	3.10
$\mathbf{G}_0$	0.16	0.03	5.87
q	0.70	0.04	15.69
R^2	0.83		

Source: Own calculations in GeoDa program.

The next step of the analysis was the estimation of the spatial panel model with fixed effects:

$$\mathbf{p}=b_0+\rho\mathbf{Wp}+b_1\mathbf{H}+b_2\mathbf{G_0}+b_3\mathbf{q}+\boldsymbol{\varepsilon}, \quad (14)$$

where **p** represents the productivity growth over the years 2000 to 2011, **H** – Human Capital and **q** – the growth of production for these years and $\mathbf{G}_0$ – Technology Gap in the year 2000.[4] The empirical results of the estimation of spatial panel model for three spatial weights matrices are presented in Table 3.

[4] The model was estimated with the sar_panel_FE (spatial lag model estimates for spatial panels with spatial fixed effects and/or time period fixed effects) MATLAB procedure available at: http://www.regroningen.nl/elhorst/software.shtml.

Table 3. Panel SAR with fixed effects results

Coefficient	**W** - *(3nn) matrix*		**W** - *contiguity matrix*		*(γ*=0.091)	
Wp	0.30	***	0.38	***	0.82	***
q	0.63	***	0.66	***	0.82	***
H	0.08	***	0.07	***	0.16	***
$\mathbf{G}_0$	-0.55	***	-0.51	***	-0.60	***
spatial fixed effects	Yes		Yes		Yes	***
time fixed effects	No		No		Yes	***
$\mathbf{R^2}$	0.95		0.95		0.94	

Source: Own calculations.

Firstly, let us consider the estimation results for 3nn and contiguity spatial weights matrix reported in 2nd and 3rd column. All the variables are highly significant (at 1% level), thus have statistically significant impact on the productivity growth in EU NUTS 2 regions. Verdoorn's coefficient is close to 0.6 which is similar to that reported in the literature - 0.5. Therefore, we conclude that increasing returns to scale exist, where faster output growth induces faster productivity growth. In addition, employment in technology and science intensive sectors also stimulate faster productivity growth. Furthermore, we conclude from the model that the larger initial gap to the technology leader a region experiences, the lower productivity growth it is likely to achieve. In fact, this negative relationship between G_0 and the part of **p** unexplained by the remaining variables might imply existence of regional divergence. Spatial-specific time-invariant effects turned out to be significant for all the applied spatial weights matrices. In contrast, time period-specific spatial-invariant effects are not significant in any of those models.

Finally, the last step of the empirical work was the estimation of distance decay parameter in the inverse distance power spatial weights matrix. According to the procedure presented in Section 2 initially we estimated the SLX model:

$$\mathbf{p}=\alpha_0 + \alpha_1\mathbf{H} + \alpha_2\mathbf{G_0} + \alpha_3\mathbf{q} + \beta_1\mathbf{WH} + \beta_2\mathbf{W\,G_0} + \beta_3\mathbf{Wq} + \boldsymbol{\varepsilon}, \quad (15)$$

using the NLS pooled estimation, where $\mathbf{W}=[1/d_{ij}^{\gamma}]_{i,j}$. From the above model we obtained γ parameter which turned out to be 0.091, which is unexpectedly small. This could suggest that the global spatial effect is present and as a result almost all NUTS 2 regions of EU interact with each other, which does not seem to be correct, especially in the context of the theoretical framework. Furthermore, incorporation of the spatial weights matrix based on the inverse distance (Table 3, column 4) in the main model (eq. 14) has not improved the estimation results in comparison to those based on 3nn and contiguity matrices.

6. Conclusions

This paper is fundamentally based on Fingleton's model which analyses the spatial process of productivity growth in regions of EU for the period 2000-2011 on the foundations of the theory of New Economic Geography. We have investigated the spatial productivity growth within the spatial setting provided by the spatial fixed effects panel model. Moreover, a new approach to defining the spatial structure, namely the parameterization of the spatial weights matrix has been presented and tested.

Concluding, the model presented provides evidence of the importance of increasing returns to scale for regional economic growth, which lead to divergence effects for EU regions. Similar implications can be observed in the case of regionally differentiated human capital. The significance of cross regional spillover implies that the impact of policy instruments on the productivity growth in one region may effect productivity growth in neighbouring regions.

The implemented method of parameterizing **W** did not improve the model, unlike in Vega and Elhorst (2013). This might be due to the fact that Vega and Elhorst in their work presented an example for 46 US states over the period 1963 to 1992. It appears that larger and more homogenous regions like the US states, observed for a longer period might give better results. Further work needs to be done as there is still a need to add more flexibility into the spatial weights matrix as the theory should determine the specification of **W**. In particular, there are other functional forms that can be specified not only with one but two or even three parameters.

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Streszczenie

BADANIE EMPIRYCZNE WZROSTU PRODUKTYWNOŚCI W UE 28 – PRZESTRZENNA ANALIZA PANELOWA

W pracy zaprezentowano przestrzenną analizę procesu wzrostu produktywności w Unii Europejskiej w oparciu o elementy teorii Nowej Ekonomii Geograficznej. Do analizy na poziomie regionów NUTS 2, zastosowano macierze wag przestrzennych w celu lepszego opisu interakcji przestrzennych pomiędzy regionami UE. Ponadto przedmiotem referatu jest próba zbadania pewnych nowych metod konstrukcji macierzy wag, w tym jej parametryzacji. W badaniu wykorzystano przestrzenny model panelowy z efektami stałymi. Zatem całość rozważań stanowi nowy element ekonometrii przestrzennej, a poprzez włączenie dodatkowej informacji na temat badanego zjawiska umożliwia wnikliwszą jego analizę.

Słowa kluczowe*: przestrzenny model panelowy, ekonometria przestrzenna, wzrost produktywności*

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The Application Of Local Indicators For Categorical Data (LICD) In The Spatial Analysis Of Economic Development

Abstract

The paper makes an attempt to apply local indicators for categorical data (LICD) in the spatial analysis of economic development. The first part discusses the tests which examine spatial autocorrelation for categorical data. The second part presents a two-stage empirical study covering 66 Polish NUTS 3 regions.

Firstly, we identify classes of regions presenting different economic development levels using taxonomic methods of multivariate data analysis. Secondly, we apply a join-count test to examine spatial dependencies between regions. It examines the tendency to form the spatial clusters. The global test indicates general spatial interactions between regions, while local tests give detailed results separately for each region.

The global test detects spatial clustering of economically poor regions but is statistically insignificant as regards well-developed regions. Thus, the local tests are also applied. They indicate the occurrence of five spatial clusters and three outliers in Poland. There are three clusters of wealth. Their development is based on a diffusion impact of regional economic centres. The areas of eastern

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and north western Poland include clusters of poverty. The first one is impeded by the presense of three indiviual growth centres, while the second one is out of range of diffusion influence of bigger agglomerations.

***Keywords**: join-count test, spatial dependence, local indicators of spatial association (LISA), exploratory spatial data analysis (ESDA), economic development, taxonomic analysis*

1. Introduction

The problem of spatial dependence is more and more frequently discussed within the framework of spatial economic research. This particular concept is of high importance since it indicates the occurrence of the intensity of certain phenomena depends on their spatial location. In case of the majority of socio-economic phenomena the existence of positive spatial dependence is their natural property.

This observation was presented in the form of Tobler's First Law of Geography according to which "Everything is related to everything else, but near things are more related than distant things" (Tobler 1970). Failure to include the existence of spatial dependence in economic research can lead to cognitive errors (Paelinck and Klaassen 1979, Anselin 1988, Haining 2003, Arbia 2006, LeSage and Pace 2009).

The aim of the paper is to identify classes of regions presenting diversified economic development levels and to apply a join-count test to examine spatial dependences as regards these classes. The study covers the situations of 66 Polish NUTS 3 regions (sub-regions) in 2011. The regions were divided into two groups presenting relatively low or relatively high levels of economic development. Groups were distinguished using taxonomic methods of multivariate data analysis.

The paper is divided into two main sections. The first section discusses statistical tests of spatial autocorrelation, presents their classification as regards a frame of reference and also data type, and it also explains tests for qualitative data in detail. The second section covers an empirical study; it presents the distinguished classes of regions and discusses the results of global and local join-count tests.

2. Tests of spatial autocorrelation for categorical data

The function of spatial autocorrelation is most often applied in the identification of spatial dependence with reference to socio-economic phenomena. Statistical tests, examining the statistical significance of spatial autocorrelation, are commonly included among the tools of exploratory spatial data analysis (ESDA). Anselin distinguished global and local tests of spatial autocorrelation (Anselin 1995). Global tests examine total spatial autocorrelation between regions, while local tests refer to the situations of individual regions; identifing spatial clusters and also outlier regions. The results of the studies can support planning of the regional development policy and spatial management.

The most frequently applied global statistical test of spatial autocorrelation is Moran's I test (Cliff and Ord 1973, 1981), while Geary's C (1954) and Getis-Ord's G (Getis and Ord 1992) tests were also proposed. Some of these statistics are also available as local indicators of spatial association (LISA). They examine quantitative data set, e.g. values of Gross Domestic Product (see Kopczewska 2006, pp. 69-70, Suchecki (Ed.) 2010, pp. 112-115, Suchecka (Ed.) 2014, p. 41).

In the field of economic research, territorial units are often classified in regard to their social and economic situations to examine regional diversification. Multivariate data analysis methods are frequently used for these purposes. Revealed classes can be equivalent (e.g. the economic profiles of regions) or ranked (e.g. the good, moderate or poor situations of regional labour markets). These classes as regards statistical measurement scales are realizations of non-metric variables such as, accordingly, nominal and ordinal variables (see Walesiak 1993). In this situation, a set of territorial units is described by qualitative (categorical) data.

In terms of qualitative data the measurement of spatial dependence in the global perspective, it is possible to follow the join-count test application (Cliff and Ord 1973, 1981, see also Kopczewska 2006, pp. 83-84, Suchecki (Ed.) 2010, pp. 110-112, Pietrzak et al. 2014). A local variant of the measure represents a family of local indicators for categorical data (LICD) (Boots 2003).

The values of the global test are determined jointly for all regions and the statistical properties of the test are well known (Cliff and Ord 1973, 1981). One of the most important issues while using a join-count test is to select the type of an adjacency matrix. This significantly affects the analysis results. A contiguity matrix is most frequently used, while other approaches can be, for example, based on applying the *k*-nearest neighbours method.

Let assume that "white" (W) means a relatively poor economic situation, while "black" (B) – a relatively good economic situation of a region. In the case of a two-colour map, the idea of join-count statistics consists in counting the white-white (WW), white-black (WB) and black-black (BB) types of neighbourhoods (Cliff and Ord 1973, 1981):

$$BB = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} x_i x_j \tag{1}$$

$$WW = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(1 - x_i)(1 - x_j) \tag{2}$$

$$BW = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - x_j)^2 \tag{3}$$

where: x_i, x_j take the value of 1 for a region belonging to the black class (B) and the value of 0 for a region belonging to the white class (W), w_{ij} – an element of an adjacency matrix.

In case of positive spatial autocorrelation occurrences the neighbourhood of units marked by the same colour should be the dominating one over the neighbourhood of units having different colours. Otherwise, a negative correlation can be adopted. If "one-colour" neighbourhoods are not dominant over the "two-colour" ones, it indicates the random distribution of a variable.

While examining statistical properties of join-count test, one of two following assumptions regarding a binary non-metric variable is assumed. The first one assumes that each territorial unit is assigned by realizations of a random variable of Bernoulli distribution $b(p), p \in (0,1)$, where p is the probability of occurring 1, similarly like in sampling with replacement. The second one assumes that the random variable records in each localization, the value 1 or zero with equal probability (similarly like in sampling without replacement).

For both assumptions, it was proved that BB and BW statistics demonstrate asymptotic normal distributions (Cliff and Ord 1973, 1981). In the test standardized BB and BW statistics are used:

$$Z_{BB} = \frac{BB - E(BB)}{\sqrt{Var(BB)}}, \qquad Z_{BW} = \frac{BW - E(BW)}{\sqrt{Var(BW)}}. \tag{4}$$

A determination of the values of Z_{BB} and Z_{BW} statistics requires knowledge of the moments of their distributions which differ according to the sampling method. In sampling with replacement, distribution moments of BB statistics are given in (5), while for BW in (6) (Cliff, Ord 1973).

$$E(BB) = \frac{1}{2} p^2 S_0,$$
$$Var(BB) = \frac{1}{4}\left[p^2 S_1 + p^3 (S_2 - 2S_1) + p^4 (S_1 - S_2)\right] \tag{5}$$

$$E(BB) = \frac{1}{2} p(1-p) S_0,$$
$$Var(BB) = \frac{1}{4}\left[p(1-p) S_2 + 4p^2 (1-p)^2 (S_2 - 2S_1)\right] \tag{6}$$

where:

$$S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij},$$
$$S_1 = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} (w_{ij} + w_{ji})^2,$$
$$S_2 = \sum_{i=1}^{n}\left(\sum_{j=1}^{n} w_{ij} + \sum_{j=1}^{n} w_{ji}\right)^2.$$

While sampling without replacement, the procedure is much more complicated (see Cliff and Ord 1973, pp. 5-6). The hypothesis regarding the lack of statistical significance of spatial autocorrelation is rejected, if the value of the Z_{BW} statistics is located in left-hand rejected area or the value of Z_{BB} statistics is located in right-hand rejected area.

A different way of testing thehypothesis of the lack of spatial autocorrelation is proposed in permuation approach. An a priori given number of colour permutations on the map is performed. Then for each permutation, the values of the BB and BW statistics are calculated. In the next steps an empirical distribution of both statistics is determined using so-called pseudo-levels of significance:

$$p_{BB} = \frac{\#\left(BB_{perm} \geq BB_{obs}\right) - 1}{k+1}, \qquad p_{BW} = \frac{\#\left(BW_{perm} \geq BW_{obs}\right) - 1}{k+1}, \tag{7}$$

where BB_{obs} and BW_{obs} mean the values of statistics for real spatial arrangement of colours, while BB_{perm} oraz BW_{perm} mean the values for permutation arrangements (k – the number of permutations).

These three statistics (BB, WW, BW) can be also used for testing the local dependencies (in relation to each single unit). However, using local tests is more difficult than using a global test. The first issue is that the neigbourhood matrix is determined separately for each region, using, for example, the contiguity matrix or k-nearest neighbours matrix. The second problem is that the statistical properties of the local test are unknown. Thus, the significance of spatial dependencies can not be statistically validated.

3. Classes of regions presenting different levels of economic development

Comparative studies examining situations of regions and territorial diversification frequently use taxonomic methods proposed in the field of multivariate data analysis (see e.g Chojnicki and Czyż 1973, Grabiński, Wydymus and Zeliaś 1989, Strahl (Ed.) 2006). The first group of these methods tends to distinguish internally homogenous and externally separable classes of units. This is the domain of cluster analysis (Hair et al. 2006, Everitt and Dunn 2001, Florek et al. 1951, Kolenda 2006, pp. 74-109). This approach is useful, among others, in the situation when the purpose of the study is to identify clusters featuring, for example, a similar job market structure, a similar economic profile, etc. (see e.g. Markowska 2012, Strahl (Ed.) 2006).

Figure 1. The 16 Polish NUTS 2 regions (dark bold line) divided into 66 NUTS 3 regions (grey line)

Source: http://stat.gov.pl/statystyka-regionalna/jednostki-terytorialne/nomenklatura-nts/nts-3-3559/.

The second group covers methods used to arrange the units in accordance with a superior criterion. These methods determine the positions of units in comparison to the other units. International literature most frequently indicates factor analysis in the field (Hair et al. 2006, Everitt and Dunn 2001). Polish literature proposes a family of linear arrangement methods (see e.g. Hellwig 1968, Grabiński 1984, Pluta 1976). One of the extensions of this concept is the TOPSIS method (Technique for Order of Preference by Similarity to Ideal Solution) proposed by Hwang and Yoon (1981) with further developments by Yoon (1987), Hwang, Lai and Liu (1993).

The second approach will be applied in the following study. The purpose of the research is to examine regional diversification of the economic development level in Poland in 2011. The study covers the situation of 66 Polish NUTS 3 regions, located in 16 NUTS 2 regions (Figure 1).

Economic development refers to the production level, economic growth, entrepreneurship, as well as the willingness to invest, and also the situation in regional job markets. The intention of the authors was to construct a set of variables which account for all the issues. In the first step the statistical data availability was examined. The set of variables also had to meet the following application criteria: comparability, clear definition of the research problem, measurability and usefulness in the description of phenomena for NUTS 3 regions, and also formal criteria: relatively high statistical variation and low statistical correlation. Table 1 presents the final set of diagnostic variables.

Table 1. The set of diagnostic variables

No	Name of variable	Unit
1	*Per capita* Gross Domestic Product	PLN
2	National economy entities included in the REGON register per 10,000 inhabitants	Entity
3	*Per capita* investment outlays in enterprises	PLN
4	Average monthly gross salaries and wages	PLN
5	Registered unemployment rate	%

Source: Authors' own elaboration.

In the next step, the TOPSIS method was applied to examine the development levels of Polish NUTS 3 regions. One of the main advantages of this method is comparing the situations of units to a positive ideal pattern as well as a negative ideal pattern (see Łuczak and Wysocki 2011, Wysocki 2010).

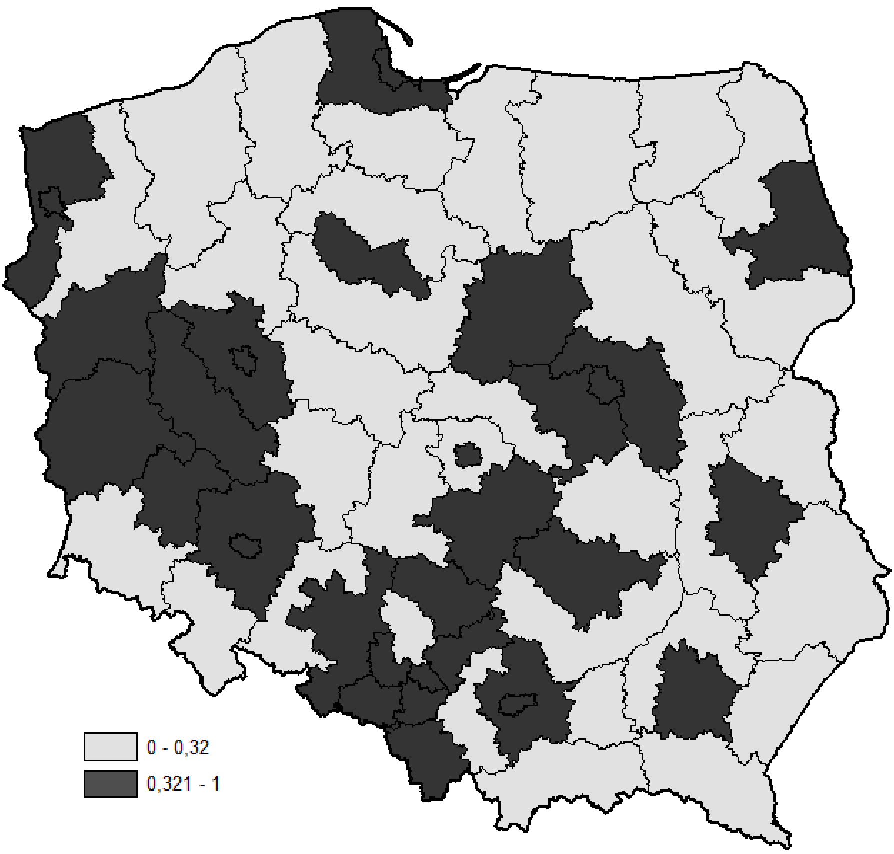
There were proposed a few ways of defining features of pattern-object, depending on the aim of the research and emipirical knowledge (see e.g. Hellwig 1968, Pluta 1976). In the presented study the positive ideal pattern takes the form of an artificial object which represents the highest real reached values of variables having a positive impact (stimulants) and the lowest real reached values of variables having a negative impact (destimulants). The negative ideal pattern is calculated inversely. The majority of selected variables indicate stimulants of economic development. Only unemployment depicts structural or economic difficulties with regional labour market.

Next, the data was normalized using unitization with zero minimum. After normalization the variables take values in the range [0.0, 1.0]. Then the values of variables with negative impact (registered unemployment rate) were translated into variables exerting a positive impact by subtracting the value of 1.

Following the above, Euclidean distances between each region (ith region) and the positive ideal pattern (PIP) and also between each region (ith region) and the negative ideal pattern (NIP), were calculated. Then the values of the synthetic measure for each region (SM_i) were calculated (Hwang and Yoon 1981):

$$SM_i = \frac{NIP_i}{NIP_i + PIP_i} \tag{8}$$

Figure 2. Two classes of NUTS 3 Polish regions presenting different levels of economic development



Source: Authors' own elaboration on the basis of data provided by Local Data Bank of the Central Statistical Office of Poland (BDL GUS).

The synthetic measure takes its values in the range of [0.0, 1.0], where 1 is determined for a region presenting the most favourable values of variables, while 0 is presented by a region with the most unfavourable values. The highest value (0.998) was recorded for the city of Warsaw (the Mazowieckie NUTS

2 region); the capital city of Poland. The second position was taken by the city of Poznań (0.703) located in the Wielkopolskie NUTS 2 region. The rest of regions took values in the range [0.654, 0.182]. The lowest value was recorded for Ełcki region, located in the Warmińsko-Mazurskie NUTS 2 region.

In the next step, on the basis of recorded values of the synthetic measure, regions were assigned to classes presenting different levels of economic development. Division criteria were presented in Nowak (1990, pp. 95-102). In the following study, due to the occurrence of the outlier value recorded by the city of Warsaw, the median value was used to distinguish classes of regions. Figure 2 presents the classification of NUTS 3 regions. The first class identifies a relatively low level (white colour), while the second class refers to a relatively high level of economic development (black colour).

There are visible clusters characterized by the low level of economic development, e.g. in the northern Poland (apart from Trójmiejski and its surrounding Gdański NUTS 3 region). Clusters featuring a relatively high level of economic development, in western Poland, southern Poland and also central Poland are also observed. Additionally, we can notice outlier well-developed regions, e.g. Białostocki and Lubelski sub-regions in eastern Poland.

4. The global join-count test in examining spatial dependence

The application of the join-count test will verify conclusions made in the previous section which were based on the visual analysis of the regional diversification of economic development levels in Poland. Table 2 presents the analysis results.

Table 2. Global join-count test results

Type of tested relation	Statistics	Expected value	Variance	Z-value
WW	10.4591	8.1230	0.6968	2.798
BB	8.8863	8.1230	0.6968	0.914
BW	13.6545	16.7538	2.0044	–2.189

Source: Authors' own calculation using spdep package (Bivand et al. 2014) of R-CRAN.

The results of join-count test are not obvious in both cases, i.e. examining of black-to-black and white-to-white relations. The test proved the occurrence of a positive spatial dependence in case of regions displaying a low level of socio-economic development. Therefore, regions featuring a low development level show a tendency towards spatial clustering.

Spatial clustering of poor regions can indicate that these regions present a slow, however, ongoing withdrawal of resources such as enterprises, human capital, etc. It results in the advancing deterioration of the situation in the regions grouped in such a spatial cluster. It also brings about the expansion of spatial cluster boundaries to more regions featuring a low development level. This situation is difficult to change and, additionally, it will probably keep advancing by further decrease in the level of development compared to well developed regions.

The results of the join-count test for black-to-black relation are not obvious. Contrary to visual assessment of the result of the taxonomic analysis presented in Figure 2, the join-count test results indicate insignificant spatial dependence for regions characterized by a relatively high development level. The global test shows an overall situation and can be affected by outlier regions. The study needs to be supplemented by a detailed analysis of spatial dependence.

5. The application of local join-count tests in examining spatial clusters

Specifying the value of local indicators for categorical data (LICD) seems to be a natural complement of the results of the global join-count test. It can become a tool for spatial cluster identification, especially in the situation when the global join-count test indicates the statistical insignificance of spatial dependence.

In the first step the contiguity matrices were determined for each region. Furthermore, 25% of regions showing the highest values of BB and WW statistics (Equations 1-2) were selected. It was assumed that for these regions there is the highest possibility of occurrence of local positive spatial dependencies.

On the basis of local join-count test statistics, five types of regions were distinguished. Figure 3 shows the analysis results. The A-type areas include the NUTS 3 regions that had the highest values of WW statistics, while the B-type areas recorded the lowest values of WW statistics. The C-type areas cover the NUTS 3 regions with the highest values of BB statistics, while the D-type areas had the lowest values of BB statistics. The E-type areas show high values of BW statistics. The white areas display statistical insignificance of BB, WW and BW statistics.

The test results revealed five spatial clusters showing different economic and spatial relations between NUTS 3 regions. The largest cluster consists of A-type NUTS 3 regions located in the eastern Poland and B-type regions. This cluster includes NUTS 3 regions of eastern, south eastern and also north eastern Poland of A-type and their B-type neighbours. This cluster comprises almost

25% of the country's total area and approximately 20% of the total population. It represents an area with the highest share of the agricultural sector in relation to other parts of Poland. The Podkarpackie, Lubelskie, Podlaskie and Świętokrzyskie NUTS 2 regions also belong to the poorest regions within the European Union. Their per capita GDP is much below the national average, while the unemployment rate is much above the national average.

The second spatial cluster was formed in north western Poland. The Koszaliński NUTS 3 region of A-type establishes the core of this cluster and its surrounding regions of B-type determine the spatial borders of this cluster.

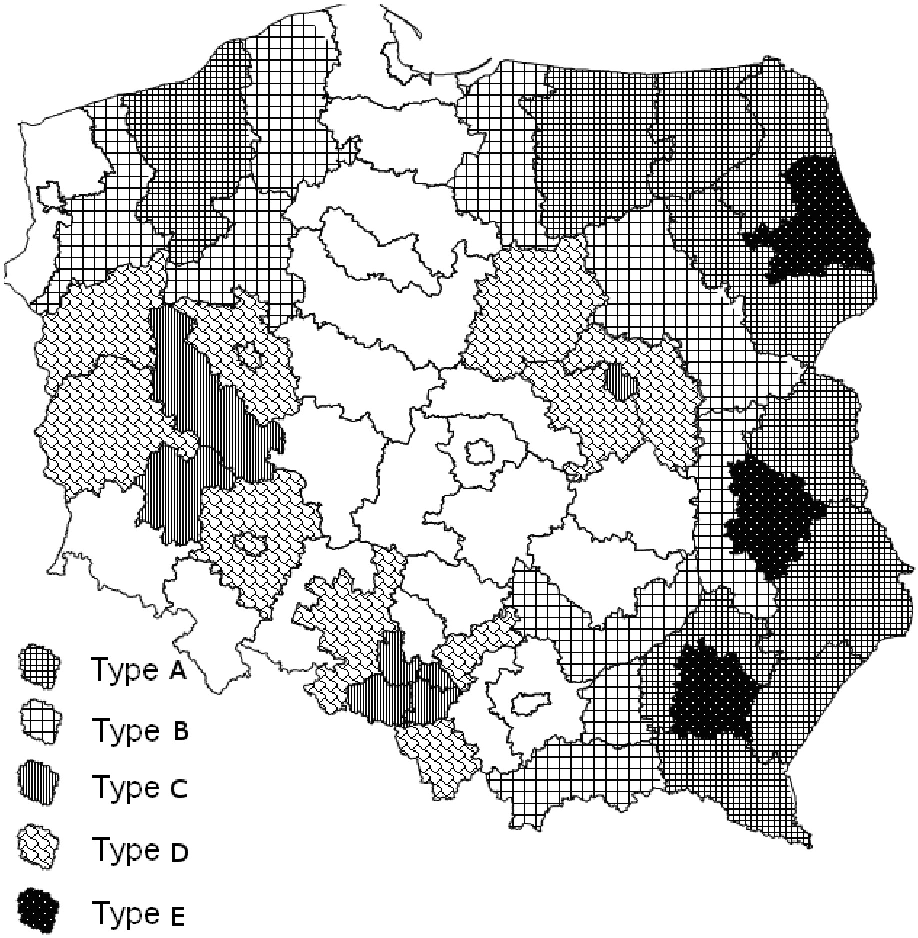
The next three spatial clusters display high economic development. Each of them consists of a well developed NUTS 3 region (or regions) of C-type with neighbouring D-type regions. The strongest economically is the spatial cluster located in central Poland with the core of the city of Warsaw. This cluster includes a greater part of the Mazowieckie NTS 2 region.

The second spatial cluster covers the most industrialized area of Poland. This cluster is formed by selected NUTS 3 regions of the Opolskie and Śląskie NUTS 2 regions. The third, and also the biggest spatial cluster includes NUTS 3 regions located in the middle of western Poland. The cluster covers the area of the Lubuskie and also a part of the Wielskopolskie and Dolnośląskie NUTS 2 regions.

The E-type areas such as the Białostocki, Lubelski and Rzeszowski NUTS 3 regions show a relatively good economic development level. All of them are located in the eastern Poland, within economically poor NUTS 3 regions. They can be defined as outliers due to their negative spatial dependences with reference to their neighbouring regions.

They establish local growth centres and are unable to form economic clusters. They do not constitute economic support for their neighbouring regions and negatively affect their situations. Outliers contribute to draining neighbouring regions due to the fact that they are a place of concentration of investment outlays and one-way flows of well qualified human resources, etc. This leads to the deterioration of situations of the other regions forming the eastern spatial cluster.

Figure 3. Local join-count tests results – five types of regions according to economic development levels and spatial dependences



Source: Authors' own elaboration.

6. Conclusions

The paper made an attempt to apply a join-count test to the analysis of spatial dependences between classes of regions displaying different economic development levels. Two approaches were included in the study. The first one examined the overall spatial interactions, while the second one concerned the particular situations of regions.

The global join-count test indicated statistically significant spatial dependence exclusively for NUTS 3 regions featuring a low level of economic development. In case of NUTS 3 regions showing relatively high development levels, the test indicated the statistical insignificance of spatial dependence.

The results pointed out the strengths and weaknesses of the global join-count test. It shows an overall situation in spatial clustering. The presence of outliers, i.e. extremely well or poorly developed regions which display statistical significance of spatial dependence of BW statistics, can significantly influence the test results.

Local join-count test facilitates more extensive analysis of the studied issue. The application of local indicators of spatial association (LISA) can indicate convergence processes, regions exceptionally exposed to poverty, processes of forming metropolitan areas etc.

The results of local join-count tests indicated the occurrence of five spatial clusters in Poland. Two of them can be seen as areas of poverty, while three of them can be classified as clusters of wealth. These clusters cover the industrialized area of southern Poland and also two areas presenting the best developed service sector in Poland. These clusters can develop due to the diffusion of innovations and other support given by regional economic centres.

The widest area is covered by regions which form clusters of poverty. The biggest one is located in the eastern Poland and spreads from the Elbląski to Nowosądecki NUTS 3 region. The majority of its regions have a poor economic situation which is also impeded by three local growth centres which take over the potential and current sources of development. These centres contribute to economic disparities in eastern Poland. The second poverty cluster covers regions located in north western Poland. This area is out of range of diffusion influence of the cities of Szczecin and the Trójmiejski NUTS 3 region.

This preliminary study can be a starting point for further research. One of the difficulties in using local join-count tests is that their statistical properties are unknown and their results cannot be validated. The second issue is considering the situations of Polish regions without reference to neighbouring foreign regions. There are macro-regions, e.g. Nysa Euro-region consisted of neighbouring regions of Poland, Germany and Czech Republic, in which cross-border cooperation exists and strong spatial relations occur. The third problem is to determine the number of related units for which the local join-count test is applied. In the study, the k-nearest neighbour method was applied. But this method can pose problems when considering regions located near the country borders.

The last problem concerns the level of territorial division, type of territorial units and their internal structure. NUTS 3 regions were analyzed in the study due to statistical data availability of the main economic statistics, e.g.

GDP, investment outlays etc. But NUTS 3 regions are territorial units established for statistical purposes, they are not administrative units. In Poland, they usually cover a few neighbouring districts located in the territory of the same province. Thus, a NUTS 3 region is usually not economically homogeneous because each of its districts realizes its individual economic development plan. The development levels and directions, and progress rates can significantly differ within the NUTS 3 unit. The second type of NUTS 3 regions covers administrative units which function independently and, in Poland, include the biggest agglomerations. Comparing different units showing different internal structures affects the analysis results, “a 5-ton elephant is not equal to 5 tons of ants”. In all the situations, additional theoretical, empirical, and simulation studies are recommended.

Acknowledgement

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Streszczenie

ZASTOSOWANIE LOKALNYCH WSKAŹNIKÓW DLA DANYCH JAKOŚCIOWYCH (LICD) W PRZESTRZENNEJ ANALIZIE ROZWOJU GOSPODARCZEGO

W artykule podjęto próbę zastosowania lokalnych wskaźników dla danych jakościowych (LICD) w przestrzennej analizie rozwoju gospodarczego. W pierwszej części omówiono testy służące do badania autokorelacji przestrzennej na podstawie danych jakościowych. W drugiej części zaprezentowano dwu etapowe badanie empiryczne obejmujące 66 polskich regionów klasy NUTS 3.

Najpierw zidentyfikowano klasy regionów prezentujące różny poziom rozwoju gospodarczego, z wykorzystaniem taksonomicznych metod wielowymiarowej analizy statystycznej. Następnie zastosowano test join-count w celu określenia przestrzennych zależności między regionami. Bada on tendencje do tworzenia się klastrow przestrzennych. Test globalny wskazuje ogólne interakcje przestrzenne między regionami, natomiast testy lokalne dają szczegółowe wyniki w odniesieniu do poszczególnych regionów.

Globalny test join-count ujawnił przestrzenne grupowanie się regionów o niskim poziomie rozwoju gospodarczego, nie potwierdził jednak zależności przestrzennych w odniesieniu do regionów dobrze rozwiniętych. Z tego względu badanie uzupełniono o zastosowanie lokalnego testu join-count. Ujawnił on występowanie pięciu klastrów *przestrzennych i trzech regionów odstających. Zidentyfikowane zostały trzy klastry bogactwa. Ich rozwój bazuje na dyfuzyjnym oddziaływaniu regionalnych centrów wzrostu. Obszar Polski wschodniej oraz północno-zachodniej zajmują klastry biedy. Sytuacja pierwszego z nich jest pogarszana przez trzy indywidualne centra wzrostu, natomiast drugi klaster znajduje się poza zasięgiem dyfuzyjnego wpływu większych aglomeracji.*

Słowa kluczowe: *test join-count, zależność przestrzenna, lokalne wskaźniki zależności przestrzennych (LISA), eksploracyjna analiza danych przestrzennych (ESDA), rozwój gospodarczy, analiza taksonomiczna*

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A Spatial Analysis Of The Knowledge - Based Economy In Poland

Abstract

The article presents a spatial analysis of the knowledge-based economy in Poland in regional terms in 2003 and 2011. Nowadays, knowledge is regarded as one of the factors of production besides land, labor and capital. The ability to create, collect and effectively use knowledge contributes to the generation of innovation, acquiring long-term competitive advantages and economic success.

Polish provinces are the basic territorial units, on which the calculations have been carried out. The period of time was purposely chosen to determine the impact of Polish accession to the European Union and the possibility of using the Structural Funds in the development of local economies based on knowledge.

The purpose of this article is to identify disparities in the use of knowledge in socio-economic life in the Polish provinces. The study was conducted using a taxonomic measure of development (one of the tools of multidimensional comparative analysis). Classification of provinces was constructed on the basis of KEI (Knowledge Economy Index) and KI (Knowledge Index) which are used by the World Bank in Knowledge Assessment Methodology (KAM). The division into four pillars (i.e. The Economic Incentive and Institutional Regime, The Innovation System, Education and Human Resources, Information and Communication Technology) attempts to explain the relationship between the factors of development.

Keywords: *knowledge-based economy, measures of taxonomy, Knowledge Assessment Methodology*

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1. Introduction

Nowadays knowledge besides land, labor and capital is considered one of the factors of production. The ability to create and absorb knowledge and its effective usage contributes to generating innovation, attaining competitive advantages and achieving economic success. Knowledge should also be considered in a broader context, taking into account at least its four main components:

- systems of education, research and propagation of knowledge,
- society with traditions, customs, culture and patterns of behaviour,
- business entities with their market potential, development strategies, methods of using knowledge and skills of its absorption,
- state authorities with a commonly practiced policy (Świtalski 2005, pp. 139-140).

Along with the growing importance of knowledge for the economy new economic terms such as "network economy" or "digital economy" emerged. The most precise concept, which describes the upward trend of the importance of knowledge for the efficiency of socio-economic system is the "knowledge-based economy". This is the type of economy, which is based on the use of knowledge and information, both in the production and distribution (OECD 1996, p. 7). Entities (i.e. people, institutions, companies, etc.) acquire knowledge, distribute it and consequently are able to use it efficiently. They increase their own competitiveness basing the business on knowledge (Kukliński 2003, p. 195).

Knowledge has no limits and can be used anytime and anywhere, causing a total blurring of boundaries while leading a company (Drucker 1997, p. 22). It should also be noted that the importance of knowledge in contemporary economic systems is constantly increasing. This is manifested by:

- globalization of markets,
- a strong product and technological competitiveness which require flexibility and commitment in a changing business environment from the entrepreneur,
- a shortening life of products and a need a prompt creation of new goods,
- integration processes of product design, technology dissemination and a wider use of marketing, which contribute to achieving success in the market,
- changing an approach to the client (taking care of his needs and the efforts of his loyalty),
- numerous mergers and acquisitions, which is an indication of the ability to combine knowledge and experience,
- the rapid development of information and telecommunications technologies, and the universality of the Internet as the most effective way of communication (Kozarkiewicz-Chlebowska 2001, p. 3).

2. Theoretical aspects of knowledge based economy

The knowledge-based economy (KBE) term appeared in the 90's of the twentieth century. It was initially associated with the United States economy, where technological advances and manifestations of innovation can be noticed. This phenomenon has fairly quickly spread to the other highly developed, global economy (Wroniecki 2001, p. 9).

The definition of KBE dates back to 1960 when P. F. Drucker used the terms "working knowledge" and "knowledge society". The "knowledge economy", "information economy", "digital economy", "network economy", "knowledge driven economy" or "new economy" were treated as synonyms for the currently used term of knowledge-based economy (Jasinski 2009, pp. 16-20). In general KBE is associated with new technologies, innovation and technical progress, which is closely linked to the Internet revolution. However, a single, universally acceptable definition of the knowledge-based economy cannot be identiefied because this term is characterized by a wide variety of interpretations.

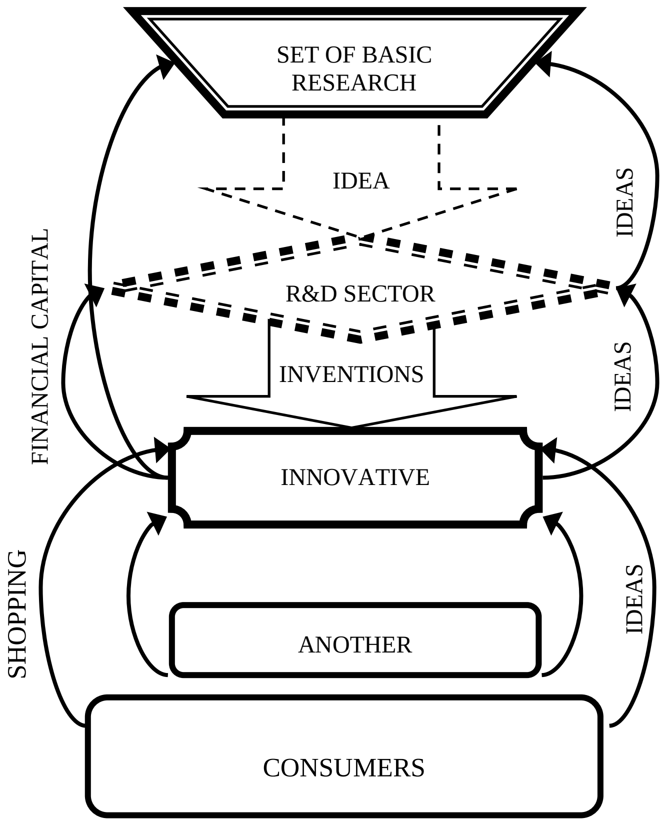
According to the Organisation for Economic Co-operation and Development (OECD) knowledge-based economy should be defined as an economy which directly based on the production, distribution and practical use of knowledge and information. Thus, according to this definition, there are three stages, which are the basis of economic development: production, distribution and implementation. However, knowledge becomes an added value, driving this development (OECD 1996, p. 7). Drucker believes that the KBE is an economic order, in which not work, capital, and raw materials, but knowledge becomes the most important resource. He also points out that the biggest challenge of KBE is removing the social inequalities (Drucker 1994, pp. 53-80).

The range of knowledge-based economy can be considered in two dimensions: the microeconomic and the macroeconomic one. The recognition of microeconomic dimension refers to business activities, which create a competitive advantage through the use of knowledge. However, a macroeconomic approach refers to the development of spheres related to the processing of information, the development of science, high technology industry and information society.

While seeking the relationship between innovation and entrepreneurship Schumpeter's theory, which was introduced into economic science in 1912, should be quoted. It was the first theor that described the genesis of innovation. It consisted of five combinations of different material components, which were combined with production capacity of a man. The meaning of these combinations is:

1. The introduction of completely new types of products to the market or specifically, one non-traditional product consumers are not familiar with, as they could not buy it before.
2. The introduction of new production techniques, i.e. methods so far untested in practice in the industry. These methods are designed not only to reduce production costs, but also they will positively influence the performance and efficiency of production, and their negative impact on the environment will be smaller than while using traditional techniques.
3. The creation of the modern market where the introduction of a new industry branch is planned.
4. The use of raw materials or semi-finished products that come from previously unknown sources.
5. The new coordination of industry, such as: the creation or fracture of monopoly position.

Figure 1. Scheme of Knowledge Based Economy



Source: own studies based (Dworak 2012, p. 33).

This perception of innovation covers many aspects that are taking place in the enterprises. It is connected with economic, technical, and organizational changes. Schumpeter pays a great attention to the fact that innovation is an economic event, but not a process involving the creation of knowledge. The result of this perception of innovation is a unique and one-time change (Schumpeter 1960, p. 60)

3. Measuring the level of the knowledge based economy

Measurement of economy knowledge is a very complex and complicated process. The Organization of the World Bank proposes Knowledge Assessment Methodology in this area, which is a part of the Knowledge for Development (K4D) program. KAM has been constantly improved since 1998. Today, this methodology consists of 148 variables (both quantitative and qualitative), which are collected for 146 countries. A regular and comprehensive analysis ensures the acquisition of more and more precise results. KAM methodology consists of four main pillars (Strożek 2013, pp. 108-109):

1. The Economic Incentive and Institutional Regime-responsible for the improvement of the economic policies and the activities of the institution. Dredging, spreading and use of knowledge in these units provide an effective action through the appropriate allocation of resources and to stimulate creativity.
2. The Innovation System – covering the activities of businesses, research centres, universities, advisory institutions and other organizations that adapt their activities to the preferences of increasingly demanding consumers.
3. Education and Human Resources – expressed through workforce that by increasing their skills, can adapt to the constantly evolving technology.
4. ICT – Information and Communication Technology – which provides effective communication and faster data transfer process. All these aspects affect the dissemination and processing of information and knowledge.

Referring to the pillars of KAM methodology, a data bank for the Polish provinces, consisting of 60 variables, was constructed. All statistics data was obtained from the Local Data Bank of the Central Statistical Office. KAM methodology is constructed for analysing national economies. Therefore, many variables had to be omitted because they did not differentiate the individual provinces significantly (e.g. trade policy or the possibility of opening own business).

Calculations were made by using the taxonomic measure of development. The process of creating the measure is as follows. Firstly the value of the coefficient of variation for all variables was calculated. This coefficient must be at a sufficiently high level. For further calculations variables for which $V_j > 10\%$ were used:

$$V_j = \frac{S_j}{\bar{x}_j} \cdot 100, \tag{1}$$

where: S_j is the standard deviation, $\bar{x}_j$ is the arithmetic mean from the sample.

The next step of analysis is to determine the nature of the variables. During grouping of all kinds of objects or areas three characters can be identified:

1. Nominants – any deviation in values of these variables is undesirable for the general characteristics of the studied phenomenon.
2. Stimulants – the higher value of these variables, the better for the general characteristics of the studied phenomenon. Therefore, what is desirable are positive parameters standing by these variables.
3. Destimulants – the lower value of these variables, the better for the general characteristics of the studied phenomenon. Therefore, what is desirable are negative parameters standing by these variables.

There is a possibility that the same variable in one study can accept the nature of stimulants and in the other one of destimulants. Everything depends on the phenomenon under study and the selection of variables. However, there should always be an unified nature of all diagnostic variables. Therefore, destimulants should be converted to stimulants and in order to do this their opposite values should be appointed (Suchecki 2010, p. 57).

The next stage of the study is an analysis of correlation coefficients values and removing variables that exhibit a strong correlation with other variables because they are carriers of the same information. As an acceptability threshold in this study the authors accepted the 0.7 value.

To standardize the variables quotient transformation was used. Thanks to that the data bank was brought to the mutual comparability:

$$z_{ij} = \frac{x_{ij}}{\bar{x}_j}, \ (i=1,\ldots,n;\ j=1,\ldots,m), \tag{2}$$

where:

- x_{ij} is the standardized variable, $\bar{x}_j$ is the mean of the population.

The next step in the study is to determine the pattern and anti-pattern of development according to the scheme:

- pattern of development $z_0 = [z_{01} \ \ z_{02} \ldots z_{0j} \ldots z_{0m}]$, where:

$$z_0 = \begin{cases} \max\limits_i z_{ij}, \text{ when the variable } z_{ij} \text{ is the stimulant,} \\ \min\limits_i z_{ij}, \text{ when the variable } z_{ij} \text{ is the destimulant,} \end{cases} \quad (3)$$

- anti-pattern of development $z_{-0} = [z_{-01} \ \ z_{-02} \ldots z_{-0j} \ldots z_{-0m}]$, where:

$$z_{-0} = \begin{cases} \min\limits_i z_{ij}, \text{ when the variable } z_{ij} \text{ is the stimulant,} \\ \max\limits_i z_{ij}, \text{ when the variable } z_{ij} \text{ is the destimulant.} \end{cases} \quad (4)$$

As in the examined phenomenon all variables were transformed into stimulants, the character of development pattern will take the highest values of test characteristics and the lowest for anti-patterns (Suchecki 2010, p. 63).

Then, the Euclidean Distance of each observation from a predetermined pattern of development should be calculated. This can be done by using the equation expressed in the form:

$$d_{i0} = \sqrt{\sum_{j=1}^{m} (z_{ij} - z_{0j})^2}, \ (i=1,2,\ldots,n), \quad (5)$$

where:

- z_{ij} is the standardized variable, z_{0j} is the pattern of development (Suchecki 2010, p. 63).

The last step of the analysis is a determination of taxonomic measure of development for all regions in Poland, which takes values from the interval (0, 10). The higher value of measure in a specific region, the greater development in this area:

$$m_i = (1 - \frac{d_{i0}}{d_0}) * 10, \ (i=1,2,\ldots,n), \quad (6)$$

where:

$$d_0 = \sqrt{\sum_{j=1}^{m} (z_{0j} - z_{-0j})^2}, \quad (7)$$

where:

- $z_{0j} - z_{-0j}$ is the distance between the pattern and anti-pattern of development (Suchecki 2010, p. 63).

4. KBE rating in the Polish provinces

Provinces were classified by using the taxonomic indicators of development, ranking from the best to the least developed ones in particular pillars, which were indicated by the World Bank for the years 2003 (see table 1) and 2011 (see table 2). Moreover, for both these years the Knowledge Economy Index (KEI) and the Knowledge Index (KI) were calculated. KEI for a specific region is the arithmetic mean of all taxonomic indicators, calculated for the individual pillars. KI is the arithmetic mean of taxonomic measures of development, calculated for the three pillars, i.e. The Innovation System, Education and Human Resources and ICT – Information and Communication Technology. KI estimated only a potential level of knowledge that exists in a specific region. Therefore, this index does not include the economic aspects of the functioning of the economy. In addition, the calculation of this measure always omitted the pillar of The Economic Incentive and Institutional Regime. If KEI is higher than KI in a given year, it means that the region takes full advantage of its knowledge potential (at a level, which is set by the KI measure). If KEI is lower than KI, it means that the region does not use all its knowledge potential. All results for the years 2003 and 2011 are presented in the tables below. A comparative analysis of all measures was made in the descriptions of tables. Time periods (i.e. 2003 and 2011) were selected, so as to see the effect of the Polish accession to the European Union and use of the Structural Funds in the development of local economies based on knowledge.

In 2003 when Poland joined the European Union, Mazowieckie province had the greatest potential of knowledge. No doubt, Warsaw had a considerable impact on this result as it is located in this region. The smallest potential of knowledge has been assigned for the Warmińsko-Mazurskie. It is also worth noting that in the midst of all the areas there is quite a large disparity (measure for the Mazowieckie is at the level of 7.77 and for Warmińsko-Mazurskie just at 1.25). The measure for the province, which occupies the second place in the ranking (Małopolskie) is at the level of 4.70, which is up by more than 3 units below the dominant – Mazowieckie (one major leader). Right behind Małopolskie there is Wielkopolskie province (4.25). The weakest one, next to Warminsko-Mazurskie was Lubelskie (1.50), Podkarpackie (1.81) and Podlaskie (1.94). KEI looks very similar to KI. The only minor differences of thess indexes can be extracted for Podkarpackie, Podlaskie, Kujawsko-Pomorskie and Pomorskie, which swapped their places in the rankings. Quite a significant decline of KEI relative to KI was recorded in Łódzkie.

Table 1. KAM values for 2003

PROVINCES	KEI	KI	Economic Regime	Innovation	Education	ICT
ŁÓDZKIE	2,87	3,14	2,06	1,49	4,73	3,20
MAZOWIECKIE	7,41	7,77	6,32	9,08	6,70	7,55
MAŁOPOLSKIE	4,47	4,70	3,78	4,90	4,01	5,21
ŚLĄSKIE	3,91	4,06	3,47	2,57	2,94	6,68
LUBELSKIE	1,70	1,50	2,30	0,85	2,83	0,80
PODKARPACKIE	2,14	1,81	3,16	1,23	2,61	1,58
PODLASKIE	2,11	1,94	2,63	0,60	2,74	2,48
ŚWIĘTOKRZYSKIE	2,17	2,17	2,18	1,99	1,94	2,58
LUBUSKIE	2,36	2,14	3,04	1,48	1,88	3,05
WIELKOPOLSKIE	4,30	4,25	4,45	3,63	4,25	4,87
ZACHODNIOPOMORSKIE	2,59	2,52	2,80	0,87	2,21	4,47
DOLNOŚLĄSKIE	3,47	3,41	3,66	1,79	2,98	5,45
OPOLSKIE	2,87	2,67	3,46	1,80	1,52	4,68
KUJAWSKO-POMORSKIE	3,25	3,05	3,84	2,05	3,02	4,08
POMORSKIE	3,15	3,43	2,31	2,05	2,48	5,75
WARMIŃSKO-MAZURSKIE	1,62	1,25	2,72	0,70	1,60	1,46

Source: own study.

Figure 2. Maps of the KEI and KI 2003

KEI

KI

Source: own studies.

To notice the spatial relationship between the studied areas visualization of the results were made and maps for individual measures were created (see figure 2). The darker colour, the higher value of the measures. The lighter colour, the lower value of the measures.

While analysing above maps it can be noticed that the smallest knowledge potential (expressed by Knowledge Index) was observed in eastern Poland, but the region looked much better in terms of Knowledge Economy Index. However, eastern provinces recorded the lowest values of the measures from all regions in Poland. A notable leader is Mazowieckie. Two southern provinces (Śląskie and Małopolskie) showed positive results. This group comprised also Wielkopolskie. Pomorskie, Kujawsko-Pomorskie and Dolnośląskie were located at the middle level. Łódzkie was in the lower group of KEI.

What seems surprising are relatively low measures observed for western provinces (Zachodnio-Pomorskie and Lubuskie). The location of these areas, directly on the border with Germany, should have a positive impact on the level of knowledge and measures of knowledge-based economy. However, in this case no such dependence was noted.

Table 2. KAM values for 2011

PROVINCES	KEI	KI	Economic Regime	Innovation	Education	ICT
ŁÓDZKIE	3,63	3,54	3,91	2,65	4,72	3,24
MAZOWIECKIE	6,42	6,31	6,76	7,66	6,31	4,95
MAŁOPOLSKIE	4,29	4,52	3,61	4,94	3,58	5,04
ŚLĄSKIE	4,47	4,67	3,86	3,40	3,14	7,47
LUBELSKIE	2,64	3,09	1,29	1,99	3,63	3,64
PODKARPACKIE	2,77	2,92	2,30	3,18	2,25	3,34
PODLASKIE	3,11	2,93	3,63	0,81	2,77	5,21
ŚWIĘTOKRZYSKIE	2,65	2,57	2,89	2,42	2,96	2,35
LUBUSKIE	1,86	1,87	1,83	0,99	1,90	2,73
WIELKOPOLSKIE	4,53	4,55	4,49	3,40	3,84	6,41
ZACHODNIOPOMORSKIE	2,59	2,43	3,07	2,41	2,77	2,10
DOLNOŚLĄSKIE	4,87	5,04	4,36	5,14	3,75	6,22
OPOLSKIE	2,74	2,68	2,91	2,20	2,24	3,60
KUJAWSKO-POMORSKIE	3,21	3,26	3,07	1,60	3,25	4,94
POMORSKIE	4,33	4,37	4,23	3,85	2,90	6,36
WARMIŃSKO-MAZURSKIE	2,01	1,91	2,30	1,26	2,07	2,40

Source: own study.

In year 2011 (similar to 2003), Mazowieckie province had the greatest knowledge potential. However, this region is characterized by a lower level of Knowledge Index than in the previous period. The smallest knowledge potential in 2011 was attributed to Lubuskie, which recorded an index fall compared to the previous period. Likewise, Warmińsko-Mazurskie, which was the last in the ranking for the year 2003 showed poor results. This region recorded a small increase of measure level compared to the previous period, however, Knowledge Index is still very low.

Developmental disparity between specific regions in Poland slightly decreased (first Mazowieckie – 6,31, previously Mazowieckie too – 7,77 and the last in the ranking Lubuskie – 1,87, previously Warmińsko-Mazurskie – 1,25). However, the pace of leveling of these inequalities is very slow.

Knowledge-based economy measure for Lubelskie reported a significantly lower level than the knowledge potential KI measure which is assigned to this region. This shows that this area does not fully exploit their potential. KEI index in the other provinces is similar to the KI index, which means that these areas use the possessed potential. However, the level of this potential could be better because general measures for the entire Poland are rather low.

In order to observe the spatial relationship (see figure 3) maps of KEI and KI, for the year 2011, as for 2003 were constructed. Similarly to figure 2, the darker colour means the higher value of the measures and the lighter colour, the lower value of the measures.

Figure 3. Maps of the KEI and KI 2011

KEI

KI

Source: own study.

Observing the map for the year 2011 the first and the most important thing is the reduction of inequalities between all areas. It may be noted that the regions, which are located on the eastern border of Poland, are marked with a little darker colour than it was in 2003. Warmińsko-Mazurskie has not improved their position. Lubuskie showed worse results than in the previous period.

Still, the one and only, not threatened leader is Mazowieckie. Just as in 2003 two southern provinces (Śląskie and Małopolskie) and Wielkopolskie performed well. Pomorskie and Dolnośląskie also joined this group. Łódzkie was characterized by a larger measure than in 2003. But it is still found in the second part of the rate ranking, though one of the largest cities in Poland is located in this area.

5. Conclusion

Measures of numerical taxonomy are very clear and do not bring the problems of interpretation. Furthermore, they allow for a graphical presentation of the results. Thanks to them, the objects can be classified and they are the best ways to verify the effectiveness of policies and effective use of available financial resources in these areas. Therefore, this article is a summary of provinces, on the basis of which knowledge-based economies on regional basis can be assessed.

Over the eight years, since Poland joined the European Union a reduction of developmental disparities in connection with the use of knowledge in social and economic life in the Polish provinces has been observed. However, it is still a long way to compensate the regional economic levels, if not impossible. The European Union Funds have a definitely high impact on the improvement of the existing situation. The most important program, influencing knowledge-based economy, was the Innovative Economy Operational Programme (IE OP) for 2007-2013. It should be noted that this article presented the test conducted to year 2011. Therefore, on the basis of these results, the effectiveness of the entire program cannot be determined but only a part of it (furthermore, the impact of the funds can often be noticeable several years after the completion of such a venture). IE OP can be called comprehensive because it had to improve not only the innovation of enterprises, but also an increase of competitiveness of science and technological progress. This improvement is manifested through computerization and use of new information and communication technologies. Moreover, IE OP leads to the fusion of science and business areas (inter alia, by R & D sector – Research and Development). It is worth mentioning that the Innovative Economy Operational Programme is a continuation of the Sectoral Operational Programme Improvement of the Competitiveness of Enterprises for years 2004-2006.

Eastern provinces, which before Poland's joining the EU were characterized by the lowest growth of all regions, were additionally covered by Operational Programme – Development of Eastern Poland (OP DEP). Thanks to this programme, eastern areas slightly reduced the gap to other, more developed, regions in Poland. OP DEP also included the aspects related to the knowledge economy. The financial support was intended to ensure driving the development of a competitive economy and the expansion of broadband lines in these areas.

There is no doubt that the innovations are often generated in urban areas. This is reflected in these regional studies. Provinces, within which large cities are located, were characterized by higher measures. It was visible for Mazowieckie (Warszawa), Dolnośląskie (Wrocław), Wielkopolskie (Poznań), Śląskie (Katowice), Małopolskie (Kraków) and Pomorskie (Trójmiasto). The exception from this rule was łódzkie, which did not receive such high results, despite the fact that within this province one of the biggest cities in Poland, Łódź is located.

Poland has still a long way to reduce a development disparities. However, it should be assumed that a good policy and rational use of European funds will contribute to the continuous reduction of these deviations, which will lead to faster socio-economic development in the whole country. These strategies cannot be constructed only on the basis of guesses and predictions. They must be supported by actual calculations.

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Streszczenie

PRZESTRZENNA ANALIZA GOSPODARKI OPARTEJ NA WIEDZY W POLSCE

Artykuł przedstawia przestrzenną analizę gospodarki opartej na wiedzy w Polsce w ujęciu regionalnym w latach 2003 i 2011. W dzisiejszych czasach wiedza jest uważana za jeden z czynników produkcji, obok ziemi, pracy i kapitału. Umiejętność wytwarzania i zdobywania wiedzy oraz jej efektywnego wykorzystania przyczynia się do generowania innowacji, zdobywania długotrwałych przewag konkurencyjnych i odnoszenia sukcesów gospodarczych.

Podstawowymi jednostkami terytorialnymi, na których przeprowadzono obliczenia są polskie województwa. Okres czasowy został dobrany w ten sposób, aby zobaczyć jaki wpływ na rozwój lokalnych gospodarek opartych na wiedzy miało wstąpienie Polski do Unii Europejskiej i możliwości korzystania z Funduszy Strukturalnych.

Celem artykułu jest wskazanie dysproporcji wykorzystania wiedzy w życiu społeczno-gospodarczym w polskich województwach. Badanie zostało przeprowadzone przy użyciu taksonomicznego miernika rozwoju (jednego z narzędzi wielowymiarowej analizy porównawczej). Klasyfikacja województw została skonstruowana na podstawie indeksów KEI (Knowledge Economy Index) oraz KI (Knowledge Index), wykorzystywanych przez Bank Światowy w metodologii KAM (Knowledge Assessment Methodology). Uwzględnienie czterech *głównych filarów (tj. system bodźców ekonomicznych, system innowacyjny, edukacja i jakość zasobów ludzkich oraz nowoczesna infrastruktura informacyjna) umożliwiło wskazanie relacji pomiędzy poszczególnymi czynnikami rozwoju.*

***Słowa kluczowe**: gospodarka oparta na wiedzy, taksonomiczny miernik rozwoju, metodologia KAM (Knowledge Assessment Methodology)*

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Spatial Diversification Of The Regional Expenses On Culture In Poland 2003-2012

Abstract

Following the completion of the process of decentralization of the public administration in Poland in 2003, a number of tasks implemented so far by the state authorities were transferred to the local level. One of the most significant changes in the methods of financing and management of the local authorities was the transfer of culture and national heritage-related tasks to a group of the own tasks implemented by local governments. As a result of the decentralization process, the local government units in Poland were given a significant autonomy in determining the purposes of their budgetary expenditure on culture. At the same time they were obliged to cover these expenses from their own revenue.

This paper focuses on the analysis of expenditure on culture covered by the provincial budgets, taking into consideration the structure of cultural institutions by their types in the years 2003, 2006, 2010 and 2012. To illustrate the diversity of the expenditure on culture by the type of the institutions in particular provinces, one applied the location quotient (LQ), which reflects a spatial distribution of expenditure on culture in relation to reference expenses incurred by the cultural institutions in Poland.

Keywords: *expenditure on culture, the provincial budgets, local finances, cultural institutions, location quotient (LQ)*

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1. Introduction

The main purpose of the system changes in the field of culture after the systemic transformation was the introduction of mechanisms supporting an efficient and fair management of public resources, introduction of changes in the public administration competences relating to the organisation of the culture financing process, and the introduction of new solutions in the scope of the financing, organisation and management of cultural institutions, such as decentralization of cultural institution management, increase of the autonomy of cultural institutions and development of legal frameworks for the patronage and sponsoring in this area (Wrona 2011, p 5).

Among the systemic changes in the Polish economy after 1989, the decentralization process was the most significant one in terms of the functioning of the cultural sector. This process can be divided into four stages (Kornaś 2005, p. 138).

The first stage was implemented in the years 1989-1991. It was an initial stage of the transformation, during which the book and the music markets were privatised and the process of decentralization of public tasks related to the dissemination of culture was initiated. During this period, most of the existing cultural institutions, including libraries, community centres, day-care rooms, clubs and some museums, were taken over by the communes. Transfer of the cultural institutions to the communes resulted not only from the implementation of the assumptions of a new, democratic state, but was also dictated by its poor economic condition (Przybylska 2007, p. 52-55).

The second stage implemented in the years 1991-1993 was an attempt to carry out a system reform of cultural institutions. A clear decentralization in the management of cultural institutions was reflected in their new division, corresponding to the three organizational levels of the country. The first level refers to cultural institutions of great significance to the national culture, which are under a direct care of the Ministry of Culture and Art, and which are financed by the mentioned Ministry. The second level refers to institutions which are under the care of the state. These institutions are supervised and financed by provincial governors, with a clear support of the central-level governmental institutions. The third level refers to institutions subordinated to local government units, which are supported by the provincial level authorities. In 1991 the Act pertaining to the organization and conduct of cultural activity (Dz. U. /Journal of Laws/ of 1991 no 114, item 493) was adopted, which, with several amendments, still remains in force.

The third stage of decentralization in the field of culture took place in the years 1993-1997. During this period no significant continuation of the process of decentralization in culture occurred. In this period of time one could see almost a renaissance of the central model of control and management of cultural institutions. However, there were many gestures from the central government, the purpose of which was to emphasise the caring role of the state towards the cultural sphere.

The fourth stage of decentralization commenced in 1997 and lasted till 2001. In the above mentioned period the decentralization reform was completed. Self-government provinces, districts and communes appeared. The provincial government units became the organizers of the majority of the state cultural institutions (Przybylska 2007, p. 52-55).

The process of decentralization of public administration resulted in changes in the role of particular public bodies in the organisation and financing of cultural activities. Nevertheless, despite the changes described above, the role of the state bodies in this area is still significant. It results from the role assigned to the state bodies, serving as regulatory institutions in the scope of the organisation and financing of cultural activities and as direct organizers of cultural institutions (Ministry of Culture and National Heritage 2009, p.17-19).

2. Analysis of expenses incurred on culture by local government units in the years 2003-2012

After 2001 one approved the final concept of the organization and financing of cultural activities in the decentralized public administration, which meant a more effective functioning of the cultural institutions and financing them to a greater extent by local governments. This may be evidenced by an increase in the years 2003, 2006, 2010 in the expenses incurred by the local government budgets, mainly of the provinces, communes and cities with district rights, on culture and national heritage protection. And thus, in 2003 the expenditure amounted to PLN 2,629 million, in 2006 - to PLN 4,239 million, in 2010 – to PLN 7,,006 million, and in 2012 decreased to PLN 6,847 million. Also the expenses per one inhabitant increased from PLN 68.84 in the first analysed year (2003) to PLN 183.47 in the year 2010 and PLN 177.96 in 2012.

Taking into consideration the institutional structure, one can notice that the highest expenses in particular provinces were incurred on the activity of community centres, day care rooms and clubs. In the analysed period, the local governments allocated over PLN 715 million in 2003, nearly PLN 1,107 million in 2006, PLN 2,225 million in 2010 and PLN 1,999 in 2012 for this purpose.

The largest expenditure on culture and national heritage protection in the analysed period was recorded in the Mazowieckie Province. They amounted to

PLN 44,779 million in 2003 and PLN 780, 899 million in 2006. In 2010 they were as high as PLN 1205208 million and in 2012 reached the level of 196262. On the other hand, the least expenditure on culture was recorded in the Świętokrzyskie Province, however, an upward trend in this area was noticed. In 2003 the total funds allocated for culture by the local government in this province amounted to PLN 60,744 million, in 2006 the sum increased to the amount of PLN 92,269 million, whereas in 2010 the expenditure amounted to PLN 209,347 million.

The observed trend probably results from the fact that the development of culture is increasingly more often perceived by the local government administration as an essential element in the formation of the regional identity and regional development.

To conclude, it needs to be emphasised that only the district level did not turn out to be a good culture organizer. The reasons for this situation may be considerably limited financial resources of the district authorities. Nowadays one considers the option of depriving the district level of the duties related to the organization and financing of cultural activities, and taking over the district cultural institutions by the cities.

The analysis of expenses incurred on culture by local government units covers the period from 2003 to 2010. One compared expenses of provinces in three selected years: 2003, 2006 and 2010.

Table 1 presents expenses incurred by local government units on culture and national heritage protection, according to selected sections of the budget classification in 2003, 2006, 2010 and 2012.

Provincial budget expenses on culture and national heritage protection were growing steadily in the analysed period. In 2003 they amounted to PLN 2629 million, in 2006 to PLN 4239 million and in 2010 to PLN 7006 million. The per-capita expenditure also grew from PLN 68.84 in the first analysed year to PLN 183.47 in the last year. The highest amounts in particular provinces were spent on the activities of community centers, day-care rooms and clubs. Over PLN 715 million was spent on that goal in 2003, nearly PLN 1,107 million in 2006 and PLN 2225 million in 2010. These amounts prove importance of these cultural institutions in the cultural policy pursued by local government units. In the analysed period the least money was spent on musical theatres, operas and operettas.

The highest expenses on culture and national heritage protection in the years 2003-2010 were incurred by the Mazowieckie province. In the analysed years they amounted to PLN 374,825million in 2003, PLN 780,899 million in 2006 and in PLN 1205,208 million in 2010 and PLN 936,498 in 2012. The least money on culture was spent by the Świętokrzyskie province, despite the fact that the expenses of local government units in the analysed period were growing. The above-mentioned statistical data show that in 2003 the expenses amounted to PLN 60,744 million in 2003, grew to PLN 92,269 million in 2006, reached the amount of PLN 209,347 million in 2010 and decreased to PLN 172,196 in 2012.

Taking into account the per-capita expenditure on culture, one has to note that the difference in expenses incurred by the Mazowieckie and Świętokrzyskie provinces in the analysed years was changing. In 2003 it amounted to PLN 25.95, in 2006 it increased to the amount of PLN 79.22, in 2010 it decreased to the amount of PLN 65.27 and PLN 41.92 in 2012.

The Śląskie province came second in terms of the total expenditure on culture in the analysed period, whereas the Dolnośląskie province ranked second in terms of the per-capita expenditure.

When analyzing the expenses incurred by local government units on museums in the years 2003-2012, one can see a considerable increase. The Mazowieckie and Małopolskie provinces were the highest spenders till the year 2012 (Mazowieckie and Dolnośląskie). In 2003 the least money was spent by the Lubuskie (PLN 7,014 million), Opolskie (PLN 8,414 million) and Podlaskie (PLN 9,487 million) provinces, in 2006 - by the Świętokrzyskie (PLN 12,848 million), Lubuskie (PLN 13,099 million) and Opolskie (PLN 19,592 million) provinces. Similarly, in 2010 local governments in the Lubuskie (PLN 29,095 million), Warmińsko-Mazurskie (PLN 32.220 million) and Podlaskie (PLN 32,420 million) provinces spent the least money, despite an over threefold increase in these expenses compared to 2003. In 2012 the lowest level of those expenditures has been noticed in Świętokrzyskie (PLN 24,718 million), Podlaskie (PLN 25,078 million) and Opolskie (PLN 285,81 million) provinces.

Expenses on library activities incurred by local government units in particular provinces were also growing and differed significantly in the analysed period. In the years 2003, 2006 and 2010 the Mazowieckie province (PLN 107,092 million in 2003, PLN 156,456 million in 2006, PLN 206,179 million in 2010 and PLN 196,262 million in 2014), the Śląskie province (PLN 98,176 in 2003, PLN 133,667 million in 2006, PLN 144,151 million in 2010 and PLN 152,544 million in 2012) and the Wielkopolskie province (PLN 64,279 million in 2003, PLN 74,585 million in 2006, PLN 100,994 million in 2010 and PLN 102,291 million in 2012) spent the most money on this goal. In 2003 the least money was spent by the Lubuskie (PLN 16,623 million), Opolskie (PLN 17,710 million) and Podlaskie (PLN 17,779 million) provinces, in 2006 - by the Lubuskie (PLN 21,326 million), Podlaskie (PLN 22,185 million) and Świętokrzyskie (PLN 22.414 million) provinces, in 2010 by the Podlaskie (PLN 31,583 million), Świętokrzyskie (PLN 31.743 million) and Lubuskie (PLN

33,113 million) provinces and in 2012 Lubuskie (PLN 31,262 million), Świętokrzyskie (PLN 34,090 million) and Podlaskie (PLN 34,343 million).

The presented analysis shows that in the entire analysed period, the local government units of the Lubuskie province responsible for the activities of libraries, spent, compared to other local government units (despite the increased expenses) the least money.

In 2003 the highest expenses on community centres and houses, day-care rooms and clubs were incurred by the Mazowieckie (PLN 8,930 million), Śląskie (PLN 85,435 million) and Małopolskie (PLN 75,208 million) provinces. In 2006 these were the Mazowieckie (PLN 134,896 million), Śląskie (PLN 115,709 million) and Dolnośląskie (PLN 106,751 million) provinces, and in 2010 and 2012 - the Mazowieckie (PLN 412,665 million in 2010 and PLN 225,561 million in 2012), Dolnośląskie (PLN 220,329 million in 2010 and PLN 195,144 million in 2012) and Wielkopolskie (PLN 100,994 million in 2010 and PLN 181,228 in 2012) provinces. The least expenses in the analysed period were incurred in 2003 by the Świętokrzyskie (PLN 16,698 million), Podlaskie (PLN 22,690 million) and Opolskie (PLN 25,715 million) provinces. In 2006 these were the Świętokrzyskie (PLN 32,307 million), Podlaskie PLN 37,108 million) and Warmińsko-Mazurskie (PLN 39,716 million) provinces, in 2010 - again the Świętokrzyskie (PLN 65,579 million), Warmińsko-Mazurskie (PLN 85,785) and Pomorskie (PLN 87,453 million) provinces, and in 2012 Świętokrzyskie (PLN 63,586 million), Opolskie (PLN 69,187 million) and Podlaskie (PLN 69,497 million) provinces.

Table 1. Expenses incurred by local government units on culture and national heritage protection, according to selected sections of the budget and province classification in the years 2003 – 2012

2003 Provinces	Total expenditure of local government units on culture in PLN thous.	Per-capita expenditure of local government units on culture in PLN	Expenditure on particular sections in PLN thous.					Number of inhabitants	Gross regional product in current prices in PLN thous.
			Museums as well as protection and care of historic monuments	Libra ries	Community centres and houses, day care rooms and clubs	Theatre	Other		
Poland	**2629085**	**68.84**	**379085**	**683579**	**715347**	**413278**	**437796**	**38190608**	**843156**
Dolnośląskie	250383	86.39	37773	53395	61208	50968	47039	2898287	65552
Kujawsko-pomorskie	126379	61.11	17708	31674	31412	22734	22851	2068058	40916
Lubelskie	126189	57.59	19741	40387	40483	10566	15012	2191162	34198
Lubuskie	64178	63.62	7014	16623	27344	4114	9083	1008771	19254
Łódzkie	194483	74.88	32563	42088	42452	48050	29330	2597262	52977

Małopolskie	226661	69.68	31763	50042	75208	31613	38035	3252885	61531
Mazowieckie	374825	72.98	44779	107092	83930	91421	47603	5135996	176073
Opolskie	64993	61.57	8414	17710	25715	6134	7020	1055595	18532
Podkarpackie	124676	59.45	23637	33951	44768	4115	18205	2097157	32780
Podlaskie	71370	59.22	9487	17779	22690	8277	13137	1205167	20210
Pomorskie	163075	74.50	29199	34281	33788	25551	40256	2188926	47445
Śląskie	335255	71.10	43767	98176	85435	40253	67624	4715260	113454
Świętokrzyskie	60744	47.03	10051	18254	16698	3546	12195	1291601	22289
Warmińsko-mazurskie	85779	60.03	13100	25830	26778	6079	13992	1428936	24868
Wielkopolskie	247216	73.58	37719	64279	58083	44361	42774	3359826	77600
Zachodnio-pomorskie	112879	66.55	12370	32018	39355	15496	13640	1696153	35477

2006 Provinces	Total expenditure of local government units on culture in PLN thous.	Per-capita expenditure of local government units on culture in PLN	Expenditure on particular sections in PLN thous.					Number of inhabitants	Gross regional product in current prices in PLN thous.
			Museums as well as protection and care of historic monuments	Libra ries	Community centres and houses, day-care rooms and clubs	Theatres	Other		
Poland	**4239141**	**111.17**	**792788**	**881607**	**1106784**	**614726**	**843237**	**38125500**	**1060031**
Dolnośląskie	392970	136.25	82076	69231	106751	56756	78156	2884245	85774
Kujawsko-pomorskie	241458	116.85	42352	41410	51647	67137	38912	2066429	50217
Lubelskie	180756	83.10	36180	49401	58344	15094	21737	2175255	40849
Lubuskie	104258	103.39	13039	21326	44627	5578	19688	1008420	24942
Łódzkie	228450	88.84	46144	46797	57522	46141	31846	2571539	65628
Małopolskie	378994	115.98	84102	68003	95832	59303	71755	3267731	78789
Mazowieckie	780899	151.20	173979	156456	134896	164535	151031	5164614	229212
Opolskie	120230	115.12	19592	24032	42548	10654	23404	1044348	23338
Podkarpackie	184699	88.08	38571	41869	66228	5401	32630	2096972	39894
Podlaskie	120129	100.31	15764	22185	37108	9240	35832	1197611	24427
Pomorskie	260068	118.16	65364	39344	50786	28728	75846	2201066	60250
Śląskie	493897	105.60	72041	133667	115709	60506	111974	4676982	137959
Świętokrzyskie	92269	71.98	12846	22414	32307	4922	19779	1281791	27084
Warmińsko-mazurskie	138459	97.02	20441	31601	39716	10087	36614	1427092	29977
Wielkopolskie	325711	96.52	48029	74585	90456	49882	62758	3374648	98806
Zachodnio-pomorskie	195894	115.67	22266	39286	82306	20761	31275	1693530	42887

2010 Provinces	Total expenditure of local government units on culture in PLN thous.	Per-capita expenditure of local government units on culture in PLN	Expenditure on particular sections in PLN thous.					Number of inhabitants	Gross regional product in current prices in PLN thous.
			Museums as well as protection and care of historic monuments	Libra ries	Community centres and houses, day-care rooms and clubs	Theatres	Other		
Poland	**7006228**	**183.47**	**1216886**	**1145187**	**2224730**	**691804**	**1727621**	**38529900**	**1416585**
Dolnośląskie	648662	225.46	108195	84013	220329	58970	177155	2877060	116367
Kujawsko-pomorskie	347588	167.95	88684	55522	102676	32778	67928	2069592	65029
Lubelskie	319356	148.20	42723	70585	113121	17584	75343	2154899	53820
Lubuskie	243035	240.46	29095	33113	95916	6655	78256	1010709	31985
Łódzkie	396122	156.05	54791	64624	100854	86728	89125	2538430	86257
Małopolskie	619790	187.57	170967	84344	152262	54125	158092	3304313	104842
Mazowieckie	1205208	230.33	220117	206179	412665	156682	209565	5232527	309729
Opolskie	216874	210.58	43737	32312	89257	10777	40791	1029889	31271
Podkarpackie	311265	148.03	58251	56232	123246	8272	65264	2102716	53400
Podlaskie	239453	201.36	32420	31583	76967	10616	87867	1189179	32559
Pomorskie	427837	191.38	68195	55611	87453	59784	156794	2235537	80329
Śląskie	713775	153.88	120907	144151	175403	62503	210811	4638517	184720
Świętokrzyskie	209347	165.06	34833	31743	65579	6791	70401	1268308	36609
Warmińsko-mazurskie	247691	173.50	32220	40961	85785	20283	68442	1427614	39063
Wielkopolskie	538386	157.69	71344	100994	176437	66509	123102	3414205	134187
Zachodnio-pomorskie	321839	190.04	40408	53219	146779	32747	48686	1693533	55197

2012 Provinces	Total expenditure of local government units on culture in PLN thous.	Per-capita expenditure of local government units on culture in PLN	Expenditure on particular sections in PLN thous.					Number of inhabitants	Gross regional product in current prices in PLN thous.
			Museums as well as protection and care of historic monuments	Libra ries	Community centres and houses, day-care rooms and clubs	Theatres	Other		
Poland	**6847050**	**177.69**	**1099519**	**1181354**	**1999044**	**722771**	**1844362**	**38533300**	**1596378**
Dolnośląskie	700342	240.23	100343	87553	195144	112393	204909	2914400	137180
Kujawsko-pomorskie	318382	151.77	76824	56665	95078	32915	56900	2096400	70913
Lubelskie	383909	177.03	74971	75670	139869	18908	74491	2165700	61180
Lubuskie	172544	168.65	34945	31262	76746	7098	22493	1023300	35018
Łódzkie	489330	193.52	67392	69719	104253	69966	178000	2524700	97146

Małopolskie	544234	162.44	88551	90767	150955	62904	151057	3354100	118170
Mazowieckie	936498	176.92	196262	191316	225561	135392	187967	5301760	361524
Opolskie	167184	165.15	28581	29855	69187	10015	29546	1010200	33217
Podkarpackie	305963	143.72	59963	61276	121053	7340	56331	2130000	59011
Podlaskie	227940	189.99	25078	34343	69497	12849	86173	1198690	35219
Pomorskie	500040	218.67	60463	64515	125533	58492	191037	2290100	91280
Śląskie	807301	174.72	132246	152544	177845	72691	271975	4615870	202679
Świętokrzyskie	172196	135.00	24718	34090	63856	6444	43088	1274000	38969
Warmińsko-mazurskie	223179	153.71	30830	42925	76499	25773	47152	1450700	43090
Wielkopolskie	551818	159.54	61582	102291	181228	57830	148887	3462200	150344
Zachodnio pomorskie	346190	201.02	36770	56563	126740	31761	94356	1721405	60286

Source: own study on the basis of data from relevant statistical yearbooks of the Central Statistical Office.

In the analysed period one also saw increased expenses incurred by particular provinces on theatres. In 2003 the highest expenses for this purpose were incurred by the Mazowieckie (PLN 70,340 million), Dolnośląskie (PLN 24,845 million) and Wielkopolskie (PLN 23,360 million) provinces. In 2006 these were the Mazowieckie (PLN 164.535 million), Kujawsko-Pomorskie (PLN 67,137 million) and Śląskie (PLN 60,506 million) provinces, in 2010 the Mazowieckie (PLN 156,682 million), Wielkopolskie (PLN 66,509 million) and Łódzkie (PLN 86,728 million) and in 2012 Mazowieckie (PLN 135,392 million), Dolnośląskie (PLN 112,393 million) and Śląskie (PLN 72,691 million) provinces. The least expenses on theatres in the years 2003-2012 were incurred by the Świętokrzyskie, Lubuskie and Podkarpackie provinces.

3. Analysis of expenses on culture incurred by the provinces in spatial terms in the years 2006 and 2012

The general description of expenses incurred by particular provincial governments for cultural institutions shows that these expenses are characterized by spatial diversity. Taking this into account, it seems advisable to perform a comparative analysis of the average of these expenses in Poland.

One of the tools of the spatial quantitative analysis are the location quotients (LQ) calculated for the expenditure of provincial governments on particular cultural institutions.

In general, the location quotients (also known as concentration indices) (Suchecki 2010, pp. 135-139) are applied in the analysis of the spatial distribution of dependence relations between two variables, in this case between the total expenditure on culture and the expenditure on the types of cultural institutions. To calculate the location quotient value, one uses concentration indices determined on the basis of the Lorenz concentration curve. The Lorenz curve is a useful tool because it illustrates a natural order of distributions from the most even one to the most concentrated one (Suchecki 2010, pp. 135-139).

While interpreting the LQ values, one should take into consideration the values above and below unity. The value of LQ >1 indicates that in the analysed province the expenditure on a particular type of cultural institutions is higher than the average expenditure in Poland, while LQ<1 indicates that the provincial government expenditure on a particular type of cultural institutions is lower than the average expenditure in the reference area.

Detailed results of this analysis for the year 2006 and 2012 are presented in table 2. Provinces with expenditure on cultural institutions above the average expenditure in Poland were marked in bold (the best ones), while provinces below the average national expenditure were marked in italics (the worst ones).

The information presented in the table shows that in the analysed years, the location quotient assumed positive values. However, the values were quite diversified, which may indicate an uneven distribution of the provincial government expenditure on particular types of cultural institutions.

Table 2. Values of the location quotient (LQ) for provincial expenditure on particular types of cultural institution in the years 2006 and 2012

	2006	Museums LQ1	Libraries LQ2	Community Center and Clubs LQ3	Theaters LQ4	Others LQ5
Dolnośląskie	1	1,12	0,85	1,04	1,00	1,00
Kujawsko-pomorskie	2	0,88	0,78	0,77	**1,81**	0,76
Lubelskie	3	1,11	**1,37**	1,29	0,60	*0,63*
Lubuskie	4	0,73	1,07	1,78	0,40	1,03
Łódzkie	5	1,05	0,96	0,94	1,36	0,68
Małopolskie	6	1,18	0,85	0,96	1,07	0,94
Mazowieckie	7	1,14	0,92	0,63	1,39	0,93
Opolskie	8	0,91	1,01	1,42	0,64	1,02
Podkarpackie	9	1,20	1,17	**1,47**	*0,22*	0,95
Podlaskie	10	0,73	0,92	1,23	0,55	**1,56**
Pomorskie	11	**1,33**	*0,72*	*0,74*	0,75	1,45
Śląskie	12	0,79	1,31	0,90	0,85	1,15
Świętokrzyskie	13	0,79	1,24	1,43	0,39	1,15
Warmińsko-mazurskie	14	0,82	1,14	1,14	0,52	1,38

Wielkopolskie	15	0,79	1,11	1,07	1,06	0,97
Zachodniopomorskie	16	*0,64*	1,02	1,71	0,78	0,85
	2012					
Dolnośląskie	1	0,86	*0,70*	0,92	**1,47**	1,05
Kujawsko-pomorskie	2	**1,44**	0,99	0,98	0,94	0,64
Lubelskie	3	1,27	1,19	1,30	0,49	0,75
Lubuskie	4	1,34	1,12	**1,62**	0,41	*0,51*
Łódzkie	5	0,84	0,81	*0,71*	1,32	1,32
Małopolskie	6	1,00	0,96	0,94	1,08	1,02
Mazowieckie	7	1,20	1,09	0,76	1,26	0,69
Opolskie	8	1,12	1,09	1,50	0,60	0,69
Podkarpackie	9	1,31	**1,25**	1,46	*0,24*	0,74
Podlaskie	10	0,75	0,96	1,15	0,59	**1,55**
Pomorskie	11	0,77	0,77	0,88	1,13	1,45
Śląskie	12	1,03	1,10	0,76	0,86	1,26
Świętokrzyskie	13	0,97	**1,25**	1,38	0,39	1,01
Warmińsko-mazurskie	14	0,86	1,11	1,17	1,09	0,78
Wielkopolskie	15	0,71	1,10	1,15	1,02	1,02
Zachodniopomorskie	16	*0,70*	1,00	1,32	0,92	1,07

Source: own study on the basis of data from table 2.

To provide a more detailed description of the diversification of the expenditure on cultural institutions in particular provinces, one calculated the location quotient growth rates. The relevant values are presented in table 3.

In the case of expenditure on museums, the highest location quotient growth rates in the analysed years were recorded in Lubuskie and Kujawsko-Pomorskie provinces. It means that expenses incurred by these provinces for this purpose were growing in the analysed period faster than the average corresponding expenses for Poland. The lowest growth rates were recorded in Łódzkie, Dolnośląskie and Pomorskie provinces.

In the analysed period, the highest increase in expenditure on libraries, compared to the average national expenditure, was recorded in Mazowieckie, Opolskie, Podkarpackie and Świętokrzyskie provinces. A decrease in these expenses was recorded in Dolnośląskie, Łódzkie and Zachodniopomorskie provinces.

Table 3. Values of the location quotient growth rates for provincial expenditure on particular types of cultural institution in the years 2006 and 2012

$DLQ_i=(LQ_{2012}-LQ_{2006})/LQ_{2006}$	Museums DLQ1	Libraries DLQ2	Community Center and Clubs DLQ3	Theaters DLQ4	Others DLQ5
Dolnośląskie	-0.23	-0.17	-0.11	0.47	0.05
Kujawsko-pomorskie	0.64	0.28	0.27	-0.48	-0.16
Lubelskie	0.14	-0.13	0.01	-0.19	0.19
Lubuskie	0.85	0.05	-0.09	0.03	-0.50
Łódzkie	-0.21	-0.16	-0.24	-0.03	0.93
Małopolskie	-0.15	0.12	-0.02	0.01	0.08
Mazowieckie	0.06	0.19	0.20	-0.09	-0.26
Opolskie	0.23	0.09	0.05	-0.06	-0.32
Podkarpackie	0.10	0.07	-0.01	0.13	-0.23
Podlaskie	0.03	0.04	-0.07	0.06	-0.01
Pomorskie	-0.42	0.06	0.19	0.50	0.00
Śląskie	0.31	-0.16	-0.16	0.01	0.10
Świętokrzyskie	0.23	0.00	-0.03	-0.01	-0.12
Warmińsko-mazurskie	0.04	-0.03	0.02	1.09	-0.43
Wielkopolskie	-0.10	-0.01	0.08	-0.04	0.05
Zachodniopomorskie	0.08	-0.02	-0.23	0.18	0.25

Source: own study on the basis of data from relevant statistical yearbooks of the Central Statistical Office.

In the case of community centres, the location quotient growth rates assumed the highest positive values in Kujawsko-Pomorskie, Mazowieckie and Pomorskie provinces. The lowest values were recorded in Dolnośląskie, Łódzkie and Śląskie provinces. It means that in these provinces an increase in expenditure on community centres was lower than the average increase in the reference area.

In the category of theatres, the dynamics of the LQ values for expenses incurred by provinces is strongly polarized. The highest location quotient growths were recorded for expenses incurred by Warmińsko-Mazurskie, Pomorskie and Dolnośląskie provinces, whereas the lowest ones in the Kujawsko-Pomorskie Province. In the remaining provinces, the increases and decreases in expenses incurred for this purpose were similar to the ones recorded in the reference area.

Analysis of the values and dynamics of the location quotient in a given period enables to classify particular expenses incurred by provinces on specified cultural institutions into one of the four groups presented in figure 1.

The 1st category refers to provinces in which the expenses incurred for particular cultural institutions showed a high value of the location quotient (LQ>1) and a positive dynamics of its changes (DQL>0). Provinces in which the value of the location quotient of expenses incurred for culture was low (LQ<1), but he dynamics of the changes (DQL>0) was positive, were assigned to the 2nd category. In the case of provinces classified into the 3rd category, a high value of the location quotient of expenses (LQ>1) was recorded at the beginning of the analysed period, however, the significance of these expenses has declined (DQL<0). The 4th category includes provinces characterized by a low value of the location quotient of expenses incurred for particular cultural institutions (LQ<1) and a negative dynamics of changes of

the location quotient (DQL<0).

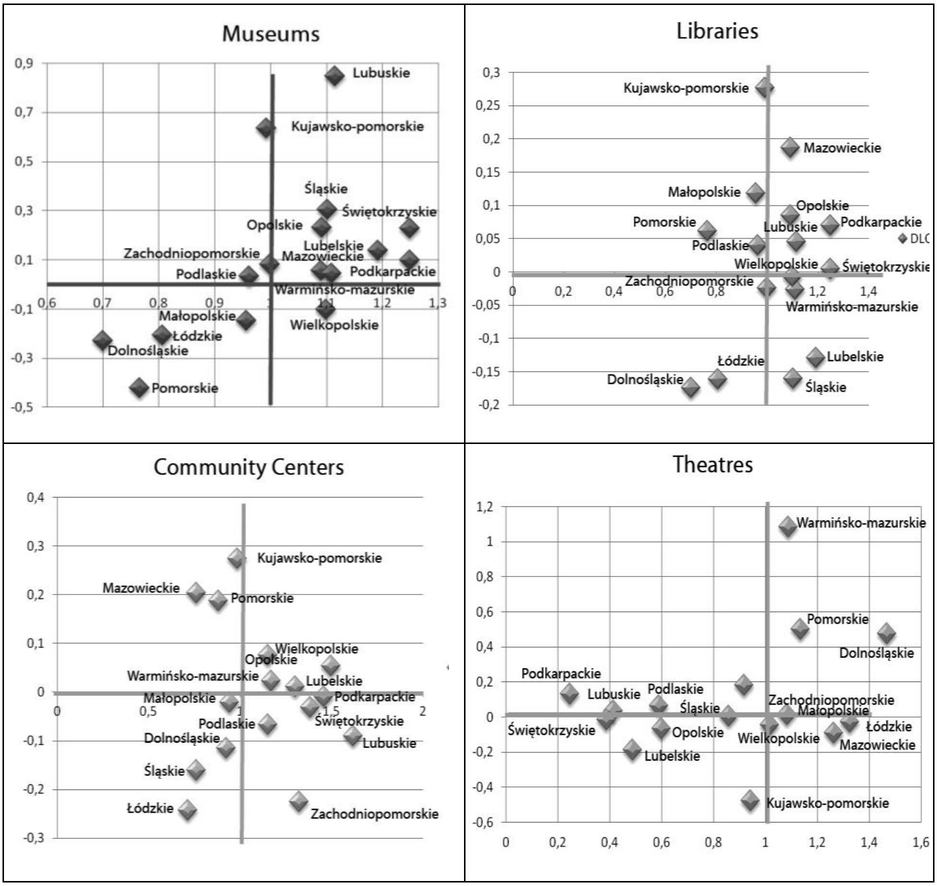
In accordance with the applied procedure, one can assume that, as far as museums are concerned, in the analysed period only the Małopolskie Province was characterized by a high value of the location quotient and a positive dynamics of its changes. Expenses incurred by the majority of provinces for museums were characterized by a low value of the location quotient in the analysed years, however the dynamics of changes of these expenses was positive. The 4th category includes Wielkopolskie and Warmińsko-Mazurskie Provinces, where the expenses incurred for museums were characterized by a low value of the location quotient and a negative dynamics of its change.

Figure 1. Diagram of classification of expenses incurred by provinces on cultural institutions, taking into account the value and dynamics of the location quotient

		LQ value	
		low	***high***
DLQ Dynamics	***positive***	**II**	**I**
	negative	**IV**	**III**

Source: own study.

Figure 2. Value of the location quotient and its dynamics for expenses incurred by provinces on particular types of cultural institutions in the years 2006 and 2012



Source: own study on the basis of data from relevant statistical yearbooks of the Central Statistical Office.

Expenses incurred for libraries characterized by a high value of the location quotient and a positive dynamics of its changes in the years 2006 and 2012 were recorded in the following provinces: Podkarpackie, Lubelskie, Świętokrzyskie and Opolskie. Expenses for libraries incurred by Kujawsko-Pomorskie, Pomorskie, Małopolskie and Podlaskie provinces, despite the low value of the location quotient, were characterized by a positive dynamics of the changes. A low value of the location quotient and a negative dynamics of its changes were recorded for expenses incurred by Zachodniopomorskie, Dolnośląskie and Łódzkie provinces. The Lubelskieskie, Warmińsko-Mazurskie, Śląskie, Wielkopolskie and Świętokrzyskie

Provinces incurred in the analysed period expenses for libraries that were characterized by a high value of the location quotient. However, the significance of these expenses has declined.

While analysing the classification of the location quotient for expenses incurred by provinces for community centres in the years 2006 and 2012, one can notice a clear declining trend in the significance of these expenses. The majority of expenses incurred by the provinces, excluding those of the Opolskie (1st category), Mazowieckie and Kujawsko-Pomorskie (2nd class) Provinces, were classified into the 3rd and 4th categories. A particularly large number of expenses was classified into the 3rd category, which may indicate a tendency to limit expenditure on institutions responsible for cultural dissemination shown by the local government units.

In the area of theatre activities one can see a division of the provincial expenses into two extreme groups. The expenses of provinces for the above purpose, due to the values of the location quotient and the dynamics of its changes, were mainly classified into the 2nd and 4th categories. A low value of the location quotient and a positive dynamics of changes in the analysed period were recorded for expenses incurred by the following provinces: Pomorskie Warmińsko-Mazurskie, Zachodniopomorskie and Podkarpackie. The worst values of the location quotient and its dynamics in the years 2006 and 2012 in relation to expenses incurred for theatres were recorded in Podlaskie, Świętokrzyskie, Lubuskie, Śląskie. Lubelskie and Dolnośląskie Provinces.

4. Conclusion

Results of the performed analyses into the development of local government expenses have clearly highlighted a spatial diversification of these expenses. It can be proven by the values of the location quotients and dynamics of their changes. The values of the above mentioned measures also enable one to group the provinces into four different categories according to the type of the cultural institutions. The obtained results allow one to conduct more advanced analyses to explore the economical factors determining the situation described above. They also show the necessity to introduce changes in the developed cultural policy in Poland.

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Streszczenie

PRZESTRZENNE ZRÓŻNICOWANIE WYDATKÓW WOJEWÓDZTW NA KULTURĘ W POLSCE W LATACH 2003-2012

W Polsce, po zakończeniu w 2003 roku procesu decentralizacji administracji publicznej szereg zadań realizowanych dotychczas przez państwo zostało przekazanych na szczebel lokalny. Jednymi z takich zadań były zadania z zakresu kultury, które zostały określone jako zadania własne samorządów. Oznacza to, że jednostki samorządu terytorialnego w Polsce posiadają znaczną autonomię w zakresie określania celów swych wydatków budżetowych na kulturę, jednakże są one zobowiązane do pokrywania tych wydatków z użyciem dochodów własnych. W artykule została przeprowadzona analiza wydatków budżetów województw na kulturę z podziałem na rodzaje instytucji *kultury w latach 2006 i 2012 w ujęciu przestrzennym.*

Słowa kluczowe: *wydatki na kulturę, budżety województw, finance lokalne, instytucje kultury, wskaźnik lokalizacji (LQ)*

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AGATA ŻÓŁTASZEK*

Leaders And Followers In The Effectiveness Of Public Safety Services In European States – A Spatial Frontier Approach

Abstract

Public safety is an important factor in both public and private life. Simultaneously it is one of the most regionally diverse sectors, due to historical, cultural, social, legal, and financial differences.Therefore, it is very difficult to compare public safety policies and facilities directly. However, assessment and comparison are crucial factors for defining the best practices and implementing the "learning-from-the-best" policy, which is important in the process of regional development and globalization. Fortunately some quantitative methods, such as DEA (Data Envelopment Analysis) enable this kind of research. DEA allows for analyzing relative effectiveness based on inputs and outputs, without incorporating procedural specifics of public safety. Therefore, the aim of this paper is to perform a regional analysis of the technical effectiveness of public safety systems in European states in 2003 and 2012 by utilizing an optimization method of DEA. Based on the results of this research countries are divided into two groups – effective and ineffective. Countries with effective systems are considered leaders. They present best practices which should be treated as benchmarks for the countries with ineffective systems, i.e. followers.

In the research, inputs of the Data Envelopment Analysis consist of human and financial resources, as these are crucial for the functioning of public safety systems. The outputs are transformations of major crime categories. The analysis has been carried out for selected European countries in 2003 and 2012. This analysis indicates that among the countries with effective public safety systems are Finland, Norway, Romania and Poland.The worst technical

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efficiency could be observed in Belgium, the UK, Estonia, and Italy, which are underperforming and wasting a large proportion of their resources.

This research indicates that despite many differences among states' public safety policies, improvement and regional development can be stimulated and achieved by implementing the "learning-from-the-best" policy.

***Keywords**: regional analysis, public safety, economics of crime, Data Envelopment Analysis (DEA)*

1. Introduction

Public safety is a very unique sector of an economy. It generally operates on a macro-level, yet its successes or failures are mostly micro-level based. The better it functions, the fewer people notice it is there. It generates no profit and exists solely for the public benefit. This sector is designed to protect people and their property from danger, injury/harm, or damage by preventing crimes, investigating them when they happen, as well as punishing and rehabilitating those who commit them. Public safety is composed of a very wide set of public and private institutions, including law enforcement, a judicial system, a corrections system, as well as fire departments, and private security and environmental safety organizations. (Ortmeier 1998, p. ix) Some of the organizations are managed at the general government level, some on local level, and others operate internationally. However, in terms of analysis, overall both the consequences and policies of public safety are usually considered and examined at the national level.

The main danger posed to public safety stems from crimes, understood as unlawful acts punishable by a state. There is however, no universal definition of a crime; it is a category created by law and therefore defined by the legislation of each country. Some categories, like murder or theft, are commonly perceived as morally wrong and needing punishment, while others vary across states, depending on the legal system. Crimes not only "create" danger but also influence the public perception of safety. Most crimes are very personal and affect, sometimes irreversibly, human life. On the other hand they generate macroeconomic costs, not only through expenses on the public safety system itself, but also as a consequence of the harm done to each person. This issue is often addressed by the field known as economics of crime, which highlights the influence and effect of individual harms in creating public losses to the economy and bringing about a decline in the quality of life. (Benson, Zimmerman 2010, pp.279-350; Eide, Rubin, Mehlop Shepherd 2006, pp.1-2).

Individual and public costs, as well as the threat to personal and public safety, make the public safety sector a crucial one in any society. Simultaneously it is one of the most regionally diverse sectors, due to historical, cultural, social, legal, and financial differences.Therefore, it is very difficult to directly compare public safety policies and facilities. Is a country “safe” because it has high expenditures on law enforcement, its criminal justice system, and its correction system? Is it safer when the number of police officers is higher? Or maybe fewer crimes mean safety? Each of these approaches is correct, but at the same time incomplete. The complexity of safety issues is an obstacle to evaluating the quality and effectiveness of public safety sectors across states. However assessment and comparison are crucial for defining the best practices and implementing the “learning-from-the-best” policy, which is important in the process of regional development and globalization. Fortunately some quantitative methods like DEA (Data Envelopment Analysis) enable these kinds of researches. DEA allows for analysis of relative effectiveness based on inputs and outputs without incorporating procedural and legal specifics of public safety. Therefore, the aim of this paper is to perform a regional analysis of the technical effectiveness of public safety systems in European states in 2003 and 2012 by utilizing an optimization method of DEA. Based on the results of this research countries are divided into two groups – effective and ineffective. Countries with effective systems are considered leaders. They present the best practices, which should be treated as benchmarks for the countries with ineffective systems, i.e. followers. The research inputs of Data Envelopment Analysis consist of human and financial resources, as these are crucial for the functioning of public safety systems. The outputs are transformations of major crime categories. The analysis has been carried out for selected European countries in 2003 and 2012, to allow for spatio-temporal studies. This analysis indicates that the countries with effective public safety systems include Finland, Norway, Romania and Poland. The worst technical efficiency could be observed in Belgium, the UK, Estonia, and Italy, which are underperforming and wasting a large proportion of their resources.

This research proves that despite many differences among states’ public safety policies, improvement and regional development can be stimulated and achieved by implementing the “learning-from-the-best” policy. Outcomes of relative measuring technical effectiveness allow to create a pattern relating inputs and outputs, in this case public safety resources versus crime levels and can be used by decision makers of the “less safe” countries to indicate some of sources of the inefficiency. As states with high inputs but poor outputs break this pattern, there should be an extra effort put into establishing the reason for underperforming. These countries should be advised to analyse the quality of their safety policies or external causes like immigration, socioeconomic inequalities, corruption as the plausible culprits of the lost effectiveness.

2. Method

One group of methods which allows for distinguishing leaders and followers is Data Envelopment Analysis (DEA). It was originally designed to optimize the production process by minimalizing inputs with given outputs or maximizing outputs with given inputs. Objects, called Decision Making Units (DMUs), are compared by combinations of inputs and outputs and divided into two subsets:

- ones that fully utilize their production potential and are efficient,
- ones that underperform and are inefficient.

Subsequently, the obtained information allows for an assessment of relative technical efficiency. It is relative inasmuch as the choice of DMUs that should be fairly homogeneous strongly influences results. Therefore, objects should be chosen wisely and carefully. The DEA method allows for researching allocation or economic efficiency, but assessment of technical efficiency is the most common as it provides an insight into the production process, i.e. how inputs are transformed into outputs. (Charnes, Cooper, Rhodes 1978, pp.430-440;Gospodarowicz 2000, pp. 240-246) In order to do this, a separate programming problem maximizing the effectiveness for each DMU is solved as follows:

$$\max_{\mu,\vartheta} \frac{\sum_1^S \mu_{rk} \cdot y_{rk}}{\sum_1^M \vartheta_{ik} \cdot x_{ik}} \tag{1}$$

$$\frac{\sum_1^S \mu_{rk} \cdot y_{rj}}{\sum_1^M \vartheta_{ik} \cdot x_{ij}} \leq 1$$
$$\mu_{rk} \geq 0, \vartheta_{ik} \geq 0$$
$$j, k = 1, \dots, N; r = 1, \dots, S, i = 1, \dots, M$$

where:

DMU_k – k^{th} Decision Making Unit, k=1,...,N,

y_{rk} – r^{th}output of k^{th} DMU, r=1,...,S,

x_{ik} – i^{th} inputof k^{th}DMU, i=1,...,M,

μ_{rk}, ϑ_{ik} – parameters maximizing the effectiveness of kthDMU. (Gospodarowicz 2002, pp.57-70)

However, DEA's biggest advantage is that it provides not only for the division of analyzed groups into leaders and followers, but moreover yields recipes for improving the situation of underperformers. For each inefficient

DMU a efficiency coefficient (Θ) representing a doable proportional increase of outcomes (in an outcome-oriented model), or decrease of inputs (in an input-oriented model) as well as vectors of slacks s– (si– for ith input) and surpluses s+ (sr+ for rth output). Together they allow for obtaining full effectiveness by transforming original vectors of inputs xk and outputs yk as follows:

in input oriented models $(\theta \cdot \mathbf{x}_k - \mathbf{s}^-; \mathbf{y}_k + \mathbf{s}^+)$ (2)

in outcome oriented models $(\mathbf{x}_k - \mathbf{s}^-; \theta \cdot \mathbf{y}_k + \mathbf{s}^+)$. (3)

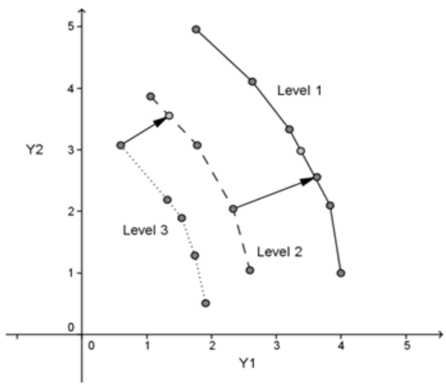
For years DEA was treated as a semi-econometric method, but lately it has been granted an estimator status. Assuming that there is indeed an effectiveness frontier defined by the production processes of all leaders on the market and the linear combination of their input-output structure, the DEA approach provides an estimate of it. Therefore, Data Envelopment Analysis methodology has been developing rapidly in many directions. It has been widely used not only in production in the classical meaning, but also in a wide range of social policies, transportation, and regional science research (the frontier is often referred as the spatial frontier) as long as there is a decision-making process considering some kind of inputs and outputs for homogeneous objects that can be compared.

Not only has the spectrum of topics changed. The classical DEA is still very useful, but the latest modifications widen its possibilities. Most of them eliminate some vices in the original approach. The new methodology includes:

- Super-efficient (Outlier robust) DEA that countermeasures for exceptional DMUs that lie above the normal efficiency frontier, (Kourtit, Nijkamp 2013, pp.761-764)
- Distance Friction Minimization (DFM) DEA that allows for optimizing each input and output separately instead of using a common efficiency coefficient, (Suzuki, Nijkamp 2011, pp.1-5)
- Context-Dependent (CD; Stepwise improvement) DEA that assumes the gradual improvement of DMU's effectiveness.

The latter incorporates a realistic idea that it is easier to improve by a little than by a lot. The CD approach assumes that the objects may be divided into more than two subsets. Each subgroup and its linear combinations defines a different level efficiency frontier. The first level frontier consists of objects effective in the classical DEA way, that is the best DMUs that, compared to others, transform 100% of inputs into outputs. The next level frontier is drawn by DMUs which are better than some, but not good enough to get to level one. Their goal should be to improve in the future so they can upgrade to the first frontier. Third level DMUs should aim at achieving the second level, which is not so distant, instead of trying to reach first level all at once. Therefore, objects on a given frontier should try to improve one level at a time (see Fig.1). This approach is quite tangible, as in many cases the input-output transformation is only a few percentage points below the nearest upper frontier, while attaining level one may require an unrealistic correction by dozens of percentage points. Therefore, the improvement is archieved step by step, hence the name - Stepwise improvement DEA. The process is based not only on the combined situation of all objects, but also on the structure of each level frontier - Context-Dependent DEA.(Suzuki, Nijkamp 2011, pp.5-6; Seiford, Zhu 2003, pp. 397-408).

Figure 1. Illustration of Context-Dependent (CD; Stepwise improvement) DEA in a output oriented model and three-level efficiency frontiers



Source: author's own in GeoGebra.

This approach is especially useful for regional comparisons where decision making is controlled by noneconomic and exogenous factors. Any changes must be not rapid, but introduced wisely and carefully, i.e. through an evolution rather than a revolution. On the other hand, many regional social issues like health, transportation, and of course public safety are not a production process per se. Nonetheless material, financial, and human resources are utilized to supply a public good and perform a social function. Effects are often non-material and qualitative rather than quantitative, but they can still be measured. Therefore, in a broad sense, some inputs are used to obtain a particular outcome, so a production occurs. All regions are unique, yet they operate under the same restrictions. They must use their resources as effectively and efficiently as possible in order to obtain goals defined by law, social policy, and public expectations. They are governed by elected representatives who are chosen by the people and for the people. As such they can be treated as a homogenous object and compared by DEA methods and used for establishing a spatial efficiency frontier (Galinienė, Dzemydaitė 2012, pp. 390-399).

3. Data

In order to assess and compare the effectiveness of public safety sectors by incorporating Stepwise improvement DEA, 29 European states were chosen: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom. The basic inputs on public safety consists of human and financial resources. Eurostat offers the number of police officers, which then has been divided by the population of each state to obtain the number of police officers per 100,000 inhabitants. The second input chosen was general government expenditures on public order and safety as a percentage of GDP. In order to present outputs of public safety, major groups of crimes were selected as representative of the true state of safety in each state:

- Homicide;*"This is defined as intentional killing of a person, including murder, manslaughter, euthanasia and infanticide. Causing death by dangerous driving is excluded, as are abortion and help with suicide. Attempted (uncompleted) homicide is also excluded. The counting unit for homicide is normally the victim (rather than the case)."*(Eurostat Crime and criminal justice);
- Violent crime;*"This includes violence against the person (such as physical assault), robbery (stealing by force or by threat of force), and sexual offences (including rape and sexual assault)."*(Eurostat Crime and criminal justice);
- Theft of a motor vehicle;*"Motor vehicles include all land vehicles with an engine that run on the road which are used to carry people (including cars, motorcycles, buses, lorries, construction and agricultural vehicles, etc.)."*(Eurostat Crime and criminal justice);
- Drug trafficking; *"Drug trafficking includes illegal possession, cultivation, production, supplying, transportation, importing, exporting, financing etc. of drug operations which are not solely in connection with personal use."* (Eurostat Crime and criminal justice).

The number of each crime category was standardized by establishing its occurrence per 100,000 inhabitants in a state. All data was obtained from Eurostat for years 2003 -2012. This combination should allow for assessing how safe or dangerous a country really is, and if the inputs are effectively utilized compared to the number of crimes which occur.

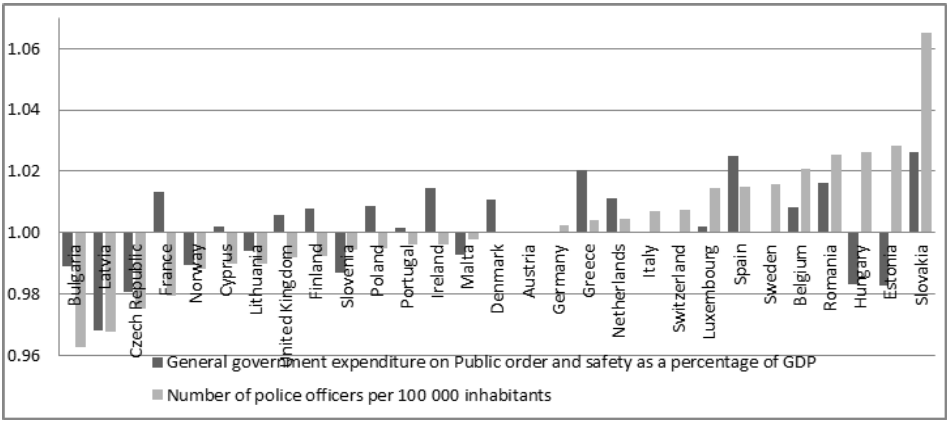
The spatial distribution of inputs is fairly even. On average a country spends 1.8% of its GDP on public order and safety. The lowest expenditures of 1% were observed in Denmark in 2002 and in Norway in 2012. The highest ones were in Bulgaria (2.8% in 2003, 2.54% in 2012). The variation coefficient is rather low – 23%. Over time changes in public expenses were small: in nine states expenditures decreased (the biggest yearly drop was in Latvia, by 3% of general government expenditures on public order and safety in GDP), in five they did not change (Austria, Germany, Italy, Sweden, and Switzerland), and in fifteen they increased (the highest in Slovakia, by 3% every year of expenditures in GDP). With respect to the police force, there were almost 340 officers per 100 000 inhabitants in each state, the median was a little lower, around 300-325 officers. The fewest policemen were in Finland (159 in 2003 & 149 in 2012) and the most in Cyprus (669 in 2003 & 611 in 2012). The percentage standard deviation was between 33% and 37%, decreasing over time. In fourteen countries the number of officers declined (the biggest decline in Bulgaria, by 4% each year) and in fifteen countries the number increased (the most in Slovakia, yearly by 7%). Therefore, both inputs were increasing at fastest pace in Slovakia. (see Table 1 & Fig. 2)

Table 1. Statistical measurement for expenditures on public safety and number of police officers in 2003 and 2012

Input	General government expenditure on public order and safety as a percentage of GDP		Average number of police officers per 100 000 inhabitants	
Year	2003	2012	2003	2012
Mean	1.78	1.8	336.1	338.13
Median	1.7	1.8	303.14	324.02
Minimum	1	1	159.19	148.8
Maximum	2.8	2.54	668.75	610.55
Variation coefficient	23%	23%	37%	33%

Source: Own calculations based on Eurostat database.

Figure 2. Average change rate of public safety expenditures and number of police officers in Europeans states in the years 2003-2012



Source: author's own based on Eurostat database.

The safety of citizens is measured by the number of crimes, however, the severity and danger level depends on the offence. Generally, there were very few homicides compared to other crimes. In 2003 there averaged 2.44 murders per 100 000 people in Europeans states, and 1.64 in 2012. The median was a bit lower, so half of the analyzed countries averaged no more than 1.52 (in 2003) and 1.08 (in 2012) per 100 000 people. The fewest homicides were registered in Malta (none in 2003) and Norway (0.54 per 100 000 people in 2012). The highest average murder rates were in Lithuania (11.22 in 2003 & 6.55 in 2012 per 100 000 people). The regional variability was quite high, as the variation coefficient was 118%. Fortunately the number of homicides per 100 000 inhabitants was systematically declining in 24 out of 29 countries, the most in France, by 10% every year. There was an annual increase in Cyprus (0.5%), Greece (4%), Austria (5%), and Malta (from 0 in 2003 to 2.16 in 2012). Violent crimes, which include most homicides as well as assault, robbery, and sexual offences, were much more common. On average there were 367 cases per 100,000 inhabitants in Europe in 2003 and 385 in 2012. The lowest violent crime rate (per 100,000 inhabitants) was noted in Romania (29 in 2003 & 31 in 2012) and the highest in the United Kingdom (1,720 in 2003 & 1,213 in 2012). As the maximum is 40 to 60 times higher than the minimum value, the mean is much higher than the median, and the percentage standard deviation of over 90% demonstrates that there is a considerable diversity among European states. Besides, the UK as well as Belgium and Sweden had over 1,000 violent crimes per 100,000 inhabitants. In fifteen states the number of these offences decreased every year, the decreasing the fastest in Latvia – 8% per year. In the remaining 14 countries police statistics showed a systematic increase, up to 12% per year in

Estonia. Car theft was one of the most common crimes in Europe. In 2003, on average 253 vehicles were stolen per 100 000 people, and in 2012 this average rose to 501. This problem was the smallest in Romania (5.2 in 2003) and Slovakia (97 in 2012), while the most cars were stolen in Sweden (752 in 2003) and Denmark (1,247 in 2012). Although the value for Romania in 2003 seems rather suspicious, there is no way of verifying it. The diversity among states is moderate, since the variation coefficient is the lowest among crimes and decreasing over time (75% in 2003 to 63% in 2012). Unfortunately, the number of motor vehicle thefts rose in 24 of 29 states, up to 40% per year in Greece. Small declines were registered in Norway 4% per year), Finland (3% per year), Sweden (2% per year), the Czech Republic (1% per year), and Slovakia (0.2% per year).

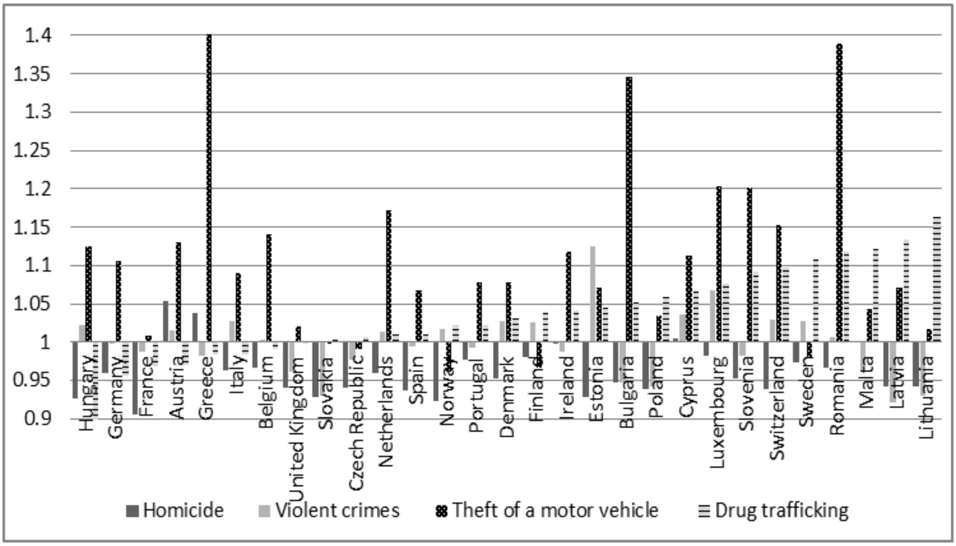
The last offence incorporated into the research was drug trafficking. On average in each state there were 68 cases in 2003 and 98 in 2012 per 100,000 inhabitants. The median is noticeably lower than the mean which, together with the variation coefficient of 110%-117%, suggests a great deal of regional diversity in this area. The fewest drug-related crimes were registered in Romania (5.2 in 2003) and Hungary (5.7 in 2012), and the most in Norway (355 in 2003) and Luxembourg (492 in 2012). Therefore, the maximum was 68 to 86 times higher than the minimum. This shows that there is a strong disproportion in Europe with respect to drug trafficking. Moreover, only eight countries had a decrease in drug-related crimes, with the largest decrease taking place in Hungary (18% yearly) and Germany (4% yearly). Most states recordede an increase in drug trafficking, up to 16% per year in Lithuania. (see Table 2 & Fig.3).

Table 2. Statistical measurement for crime categories in 2003 and 2012

Crime	Homicide per 100,000 inhabitants		Violent crimes per 100,000 inhabitants		Theft of a motor vehicle per 100,000 inhabitants		Drug trafficking per 100,000 inhabitants	
Years	2003	2012	2003	2012	2003	2012	2003	2012
Mean	2.44	1.64	367.41	385.31	253.39	501.02	67.55	97.83
Median	1.52	1.08	247.31	233.7	211.65	440.745	43.925	62.13
Minimum	0	0.54	29.04	30.62	5.21	97.37	5.23	5.74
Maximum	11.22	6.56	1720.11	1213.12	751.60	1247.48	354.81	492.14
Variation coefficient	118%	94%	98%	92%	75%	63%	110%	117%

Source: Own calculations based on Eurostat database.

Figure 3. Average rate of change in crime categories per 100 000 inhabitants in European states in the years 2003-2012



Source: author's own based on Eurostat database.

Generally, as the change rate in inputs is spread among countries the crime rates, excluding homicide, increased. This raises the questions: Which public safety systems are technically effective? Does the effectiveness vary over time?

4. Results

In order to verify the effectiveness of public safety systems in European states over 10 years – 2003-2012 – a Context-Dependent or Stepwise improvement input-oriented DEA was employed. The analysis was carried out independently for the year 2003 and then in 2012. Moreover, since in this case outputs are negative, as crimes represent public danger rather than public safety, they cannot be introduced into the DEA optimization. Therefore, each variables' value was inverse. In Malta, in 2003 there were no homicides, therefore, inversion was not possible so it was assigned a 2, which is higher than the maximum value for other states. Since the inputs are controlled by the states, while outputs are mainly exogenous, an input-oriented model was chosen.

4.1. Results for 2003

In 2003 the states were divided into four groups defining the sequential spatial frontier levels. There were nine states that had managed to fully utilize their inputs: Austria, Denmark, Finland, Luxembourg, Malta, Norway, **Poland**, Romania, and Sweden. These countries had efficiency coefficients of 100% and in their current situation could not do any better. The second level frontier is defined by nine DMUs: Bulgaria, Cyprus, France, Germany, Greece, Ireland, Slovakia, Slovenia, and Switzerland. Their performance was not outstanding, however, they did fairly well compared to other states. Their effectiveness was very diverse ranging from 44.4% in Bulgaria to 94.1% in Switzerland. In the former both inputs, expenditures and number of police officers should have been lower by 56%, additionally the police force should have been diminished by 42.6 officers per 100,000 inhabitants. Even then the number of crimes committed should have been lower: homicides by 3.7 and drug trafficking by 3.74 incidents per 100,000 inhabitants. In Switzerland the efficiency coefficient suggests that only 6% of inputs were wasted. A slight correction of expenditures was needed – 0.11% of the GDP less than is currently spent. Subsequently the number of car thefts should have been lower by 33 and drug crimes by 25 per 100,000 inhabitants. Generally, in the second level group the number of police officers was too high and the number of drug crimes exceeded expectations. The third spatial frontier consists of Belgium, Estonia, Hungary, Italy, Latvia, Lithuania, the Netherlands, Portugal, and Spain. Each is quite close to the second level – the farthest away being Italy, with overestimated inputs by 25% and in addition too many homicides by 20 per 100 000 inhabitants, while the closest was Lithuania with 5% inefficiency. These countries lie very far from the first level frontier – Italy's coefficient of 54% and Lithuania's of 66%. The main issue appears to be the high number of homicides, which needed additional adjusting by slacks. The fourth and last frontier encompassed the Czech Republic and the United Kingdom (UK), although they were less than 5% inefficiency from achieving the next upper level, while 40%-50% from the first level (see Table 3.).

Table 3. Context-Dependent DEA results for European states in 2003 by frontier level (efficiency coefficient and slacks for the closest upper lever frontier)

Frontier level	Country	Efficiency coefficient for upper level frontier [%]	Slacks					
			Expenditures on public safety [% of GDP]	Per 100 000 inhabitants				
				Police officers	Homicide	Violent crime	Theft of a motor vehicle	Drug trafficking
2	Bulgaria	44.4		42.6	3.7			3.74
	Cyprus	70		263.2			7.69	33.33
	France	90.6		102.6				83.33
	Germany	70.2						
	Greece	85.4		164.7			25	20
	Ireland	70		5.5				
	Slovakia	74.3			3.13	10	16.67	
	Slovenia	61.4						100
	Switzerland	94.1	0.11				33.33	25
3	Belgium	88.2		6.3	3.33			
	Estonia	84	0.27		1.28			
	Hungary	80			2.7			
	Italy	75.2			20			
	Latvia	89.9			1.33			
	Lithuania	94.5			2.04			
	Netherlands	91.2	0.03		5.26			
	Portugal	75.7		10.2	16.67			
	Spain	84.6		67.9	33.33			
4	Czech Rep.	94.30						
	UK	91.50	0.3		7.14			

Source: Own calculations based on STATA results. (Slack for outputs were inversed to the original form, they represent a suggested decrease in the number of crimes.)

4.2. Results for 2012

In 2012 the states were also in four frontier levels. There were ten countries with fully efficient public safety sectors: Finland, France, Hungary, Latvia, Norway, Poland, Romania, Slovakia, Slovenia, and Switzerland. The second spatial frontier encompassed nine states: Austria, Bulgaria, Cyprus, Czech Republic, Denmark, Germany, Lithuania, Luxembourg, and Malta. Their effectiveness varied from 52% in Bulgaria to 97.3% in Denmark. In most countries, besides the proportional decline of inputs suggested by the efficiency coefficient, a supplementary correction of police officers by 10 – 136 people as well as the number of homicides by 1 – 10 per 100 000 inhabitants was possible. The third frontier encompassed Spain, Sweden, Estonia, Greece, Ireland, Italy, the Netherlands, Portugal, and UK, so also on 9 DMUs. The highest efficiency was observed in Greece, which wasted less than 3% of public safety inputs (29% compared to the first frontier), while the lowest registered was Spain with 47% of wasted resources (also 47% compared to the first frontier), which required an additional change of police force by 65 officers and homicides by 7 cases per 100,000 citizens. The problem with the number of police officers was less common on this level, but the number of homicides was still too high in relation to input-output combination. Moreover, a possibility of a further decline in public expenditures on public safety is visible, varying from 0.03% of the state's GDP in Ireland to 1.04% in the UK. The only country on the fourth and last frontier was Belgium, which was fairly close to the next upper level as the efficiency coefficient was equal to 93%, with a suggestion for an additional decline in the number of police officers by 101 and homicides by 7 per 100,000 Belgians. It is interesting that Belgium creates a one-state-level frontier, especially considering that it never was the least efficient country in comparison to any of the upper level spatial frontiers. Although its efficiency coefficient put Belgium among the most inefficient countries, in the case of the first level the value of 57% was actually slightly higher than in Bulgaria, Estonia, Italy, and Spain (see Table 4).

Table 4. Context-Dependent DEA results for European states in 2012 by frontier level (efficiency coefficient and slacks for the closest upper lever frontier)

Frontier level	Country	Efficiency coefficient for upper level frontier [%]	Slacks						
			Expenditures on public safety [% of GDP]	Per 100 000 inhabitants					
				Police officers	Homicide	Violent crime	Theft of a motor vehicle	Drug trafficking
2	Austria	83.4		66.5	1.79			
	Bulgaria	52			1.14			
	Cyprus	62.1		92.5				100
	Czech Rep.	72.5		70.3	2.27			
	Denmark	97.3		10.5	1.35			
	Germany	69.6		10.4	9.09			

	Lithuania	72			1.04				
	Luxembourg	89.3		136	10				
	Malta	88.1		104.7					
3	Spain	52.9		64.5	6.67				
	Sweden	77.5			3.45				
	Estonia	88	0.12		4.35				
	Greece	97.8							
	Ireland	76.8	0.03		33.33				
	Italy	61.8		0.06					
	Netherlands	84.2	0.54		50				
	Portugal	65							
	UK	91	1.04						
4	Belgium	93.4		100.9	6.67				

Source: Own calculations based on STATA results. (Slack for outputs were inversed to the original form, they represent the suggested decrease in the number of crimes.)

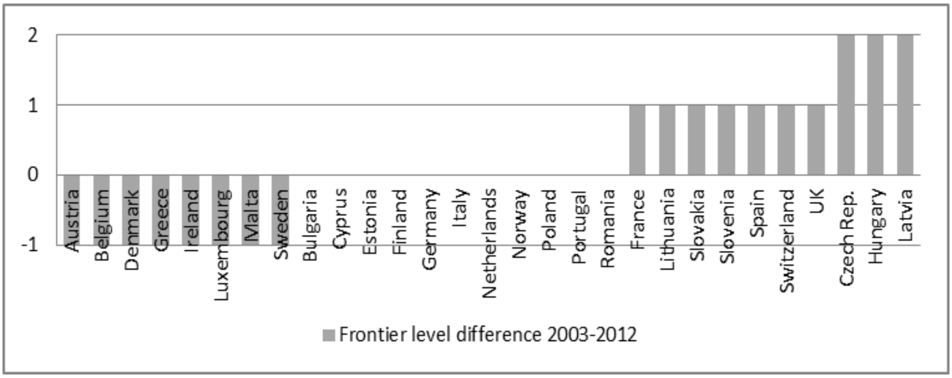
4.3. Comparison of 2003 and 2012

The conducted analysis allows for creating a spatio-temporal comparison of technical effectiveness of public safety sectors among the selected European states. Out of the 29 researched countries, eleven had a stable position between 2003 and 2012. Some, like Finland, Norway, Poland, and Romania maintained their leader status throughout the research, while others (Estonia, Italy, Netherland, and Portugal) were performing poorly. Eight countries dropped in position by one level: Austria, Denmark, Luxembourg, Malta, and Sweden, from the leader position in 2003 to the second frontier in 2012; Greece and Ireland from level 2 to 3; while Belgium fell from level 3 to the lone position on the fourth frontier. Meanwhile ten sates upgraded their efficiency. Slovakia, Slovenia, Switzerland, Hungary, and Latvia improved their public safety sectors and became leaders in 2012. The Czech Republic, Hungary, and Latvia achieved a major success by improving their efficiency by two levels.

Spatial distribution seemed rather random. In 2003 the Scandinavian countries clustered around the efficient public safety zone, however, this changed over time. Western and Southern Europe appeared to be rather inefficient in dealing with crime. In 2012 Central European countries, extending to the Balkans, were grouped as having highly effective public safety sectors.

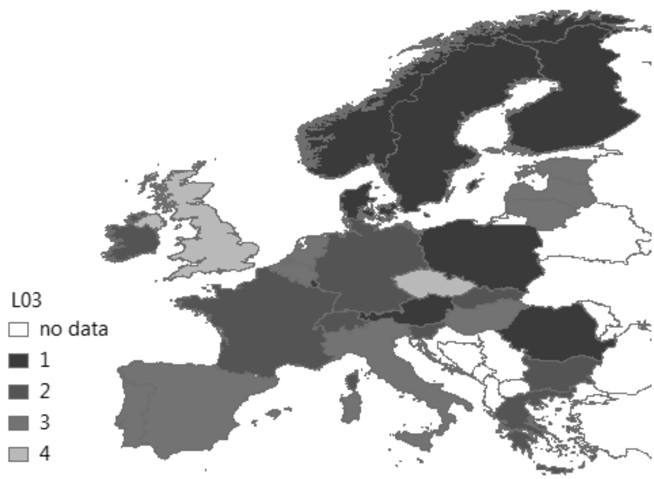
However, no international tendencies were visible. It appears that since the policy is design and carried out on a national level, the public safety sector is independent of any influence other than national. (see Figs.4,5,6).

Figure 4. Change in DEA frontier level in 2013 compare to 2003 in European states



Source: author's own.

Figure 5. Spatial distribution of Context-Dependent DEA level frontiers of European states in 2003



Source author's own in ArcMap.

Figure 6. Spatial distribution of Context-Dependent DEA level frontiers of European states in 2012

Source: author's own in ArcMap.

CD DEA results reveal some interesting facts. Firstly, it seems obvious that for inefficient states the smaller distance to a spatial frontier, the higher is the frontier's number. If a country is inefficient it should be easier to improve a little and achieve an upgrade by one level, say from frontier 3 onto 2, than jump to the first level in one round. In most instances this was the case. However, there were exceptions. Spain in 2012 was on the third level, but its inefficiency was almost the same as in the first and second frontier. This is unusual and true mostly for those countries with a low efficiency coefficient. What's more, DMUs located on the lowest frontier are not necessary the furthest from the first level. The relativity of the DEA approach means that the combination of selected DMUs influences the outcome.

The analysis results help to understand the main source of inefficiencies. Slacks that describe additional changes to the efficiency coefficient suggest that in most states the number of police officers is much too high compared to the number of crimes. Were there less people on the force, they would assure the same public safety, or at least this number of policemen should result in much lower crime rates. Moreover, there are too many homicides. Of course, in case of murders one is too many, but using a completely soulless and mathematical approach it may be said that these inputs should guarantee less homicides. It is interesting that different levels had different additional problems, which may partly reflect the source of the inefficiency and differentiation between frontier levels. What is more, the number of car thefts and persons convicted of drug trafficking, which was a major problem in 2003, did not generate any slacks in 2012.

5. Conclusions

Public safety is closely linked to both personal and public health, welfare, quality of life, and economic situation. Statistical analysis has shown that only the number of homicide declined in all but four states, while other crime rates in Europe increased in the last decade. This seems due to the severity of punishments and the crime detection rates concerning murder. For instance, in Poland in 2011 over 90% of homicide cases were solved, and only 22.5% of car thefts (Statystyki ogólne Policji 2014).

Meanwhile public safety inputs varied across time and regions, being reduced in almost half of the researched countries. This does not draw an optimistic picture, as it suggests that Europe is becoming less and less safe. However, this does not indicate whether public safety systems are, or are not, effective. Clearly the lower the crime rates the higher the effectiveness. In most cases the minimal values of each crime group allows for a place on first level frontier. The highest values result in a decline of efficiency coefficients. Also the lower the inputs (expenditures and the number police officers) the higher the effectiveness. Less resources mean that they are better utilized. Overestimation of inputs does not bring about an additional reduction of crime.[1] However, it should be reminded that relative technical effectiveness does not reflect the "quality" of safety. One police officer and $1 will default to generate higher utilization rate than a thousand. The baseline for improvement is the frontier outdrawn by leaders (as in DEA approach) or at the very least the higher efficiency frontier.

Moreover, the DEA results show that there is no spatial regularity in public safety effectiveness. Neither the richer "old" nor poorer "new" EU states, nor their northern or southern, western or eastern locastions allow for any generalizations. Among the constant leaders were Finland, Norway, Poland, and Romania. Since they should be treated as benchmarks for other states, their economic and social policy diversity is an advantage. The inefficient countries have then a real choice which best performer to follow. This research proved as well that changes can be made and that they count, as the Czech Republic, Hungary, and Latvia succeeding in upgrading their efficiency level, measured by Context-Dependent (Stepwise improvement) spatial DEA approach, by two levels in less than ten years, which was especially noteworthy for Hungary and Latvia, as they advanced into the leading group.

[1] DEA approach perceives effectiveness as derived from the input-output combination. Although it can be argued that inputs influence effectiveness and effectiveness influences outputs.

Safety is definitely an important issue overall in Europe, and as crime rates tend to rise, choices and decisions need to be made to protect people and their property from danger, harm, or damage by increasing the technical effectiveness of the public safety sector. This can be achieved by acknowledging the existence of leaders and followers in this area and implementing a "learn-from-the-best" policy as an element of regional development.

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Streszczenie

LIDERZY I UCZNIOWIE EFEKTYWNOŚCI BEZPIECZEŃSTWA PUBLICZNEGO W KRAJACH EUROPEJSKICH – PRZESTRZENNA ANALIZA GRANICZNA

Bezpieczeństwo publiczne to ważny aspekt życia publicznego i prywatnego. Jednocześnie ze względów historycznych, kulturowych, społecznych, prawnych i finansowych jest ono jednym z najbardziej zróżnicowanych przestrzennie sektorów. W rezultacie utrudnione jest prowadzenie bezpośrednich analiz porównawczych polityk i funkcjonowania aparatu bezpieczeństwa publicznego. Jednak ocena i porównania są kluczowym elementem prowadzenia polityki „najlepszych praktyk" oraz „uczenia się od najlepszych" stanowiących ważny czynnik rozwoju regionalnego i globalizacji. Istnieją metody ilościowe jak DEA (Data Envelopment Analysis), które umożliwiają prowadzenie takich badań. DEA pozwala na analizę relatywnej efektywności technicznej w oparciu o regionalne nakłady i efekty bez konieczności uwzględniania specyfiki rozwiązań proceduralnych bezpieczeństwa publicznego poszczególnych krajów, traktując system jako nietypowy proces produkcyjny. Dlatego celem artykułu jest regionalna analiza efektywności technicznej systemu bezpieczeństwa publicznego w wybranych krajach europejskich oraz określenie przestrzennej granicy efektywności. W oparciu o uzyskane rezultaty badane kraje zostaną podzielone na dwie grupy – efektywną i nieefektywną. Państwa o efektywnych systemach uznawane są za „liderów" reprezentujących „najlepsze praktyki" , którzy powinni być traktowania jako wzorce dla obiektów nieefektywnych – „uczniów".

Nakładami w przeprowadzonym badaniu metodą DEA były nakłady finansowe oraz osobowe ponieważ są one kluczowe dla funkcjonowania systemu bezpieczeństwa publicznego. Efektami zaś były przekształcone liczby występowania głównych kategorii przestępstw. Analiza została dokonana dla lat 2003 i 2012. Uzyskane wyniki sugerują, że wśród liderów znalazły się Finlandia, Norwegia, Rumunia i Polska. Najniższą efektywność techniczną odnotowano dla Belgii, Wielkiej Brytanii, Estonii i Włoch, które nie wykorzystywały w pełni swoich nakładów. Przeprowadzone badania wskazuje, że pomimo wielu różnic w polityce bezpieczeństwa publicznego rozwój regionalny może być prowadzony poprzez implementacje podejścia „ucz się od najlepszych".

Słowa kluczowe: *analiza regionalna, bezpieczństwo publicane, ekonomika przestępczości, Data Envelopment Analysis (DEA)*

Contents