A C T A U N I V E R S I T A T I S L O D Z I E N S I S
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REGIONAL INNOVATIVENESS AND SOCIO-ECONOMIC DEVELOPMENT

1. INTRODUCTION

The main objective of this paper is to measure and analyse the level of regional innovativeness in Poland as well as to analyse the relationship between innovation and regional development levels.

Due to the fact that innovativeness is a multidimensional and complex phenomenon, its measurement requires the use of methods which on the one side take into account a large set of diagnostic features characterising different fields of innovativeness, and on the other side allows to reduce the description to only one synthetic variable (Strahl 2009: 17). This approach also enables the arranging and classifying of analysed objects by the level of innovativeness (Krakowiak-Bal 2005: 71).Taxonomic methods are particularly useful in such studies. They are often used in spatial analyses to compare and group objects (countries, regions, provinces etc.) based on the level of the studied phenomenon (Suchecki 2010: 56-57).

This paper covers the construction of an aggregate innovation index with the use of four different taxonomic methods, comparing the results obtained with each of them (using Spearman correlation coefficient) and research on innovation level in the provinces in the years 2008–2012. The last part of the article focuses on the question of whether an increase in innovation is correlated with an increase in the regional development level. It contains an analysis of the relationship between the innovation level, as measured by an aggregate index, and the level of regional socio-economic development, as expressed by GDP per capita, where a basic measure of statistical dependence (Pearson's linear correlation coefficient) has been used. Due to the lack of data for GDP per capita in 2012, the analysis of relationship does not cover that year.

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2. INNOVATION INDEX

2.1. Data and Methodology

The part of the analysis covering the construction of the aggregate innovation index is a continuation of the author's previous research in this subject (see: Gajdos, Żmurkow 2012: 45-58; Żmurkow-Poteralska 2012: 67-81). The selection of the variables used in the index is based mainly on the list of 25 indicators used in the Innovation Union Scoreboard (IUS)[1] and Regional Innovation Scoreboard (RIS) methodology. Due to the fact that most of the indicators used in IUS are not available at the regional level, it was necessary to replace the missing variables with similar ones related to the same field of innovativeness. The data sources are the Local Data Bank of the Central Statistical Office of Poland and Eurostat.

The individual indicators (Table 1) illustrate the three main fields of innovativeness, which are: enablers, firm activities and outputs.

Table 1. Indicators used in the innovation index

Field	Indicator
Enablers	Doctoral students (ISCED 6) per 1 000 population aged 25–34 years
	Percentage of population aged 30–34 completed tertiary education (ISCED 5–6)
	Students in tertiary education (ISCED 5–6) as % of the population aged 20-24 years
	Human Resources in Science and Technology (HRST) as a percentage of active population
	R&D expenditure per inhabitant
	R&D units per 100 thousand population
Firm activities	Participation of industrial enterprises having incurred innovation expenditures
	Participation of enterprises in the service sector having incurred innovation expenditures
	Percentage of industrial enterprises with innovation co-operation activities
	Percentage of enterprises in the service sector with innovation co-operation activities
	Number of patents applications at the Polish Patent Office per million population
Outputs	Percentage of industrial enterprises introducing product or process innovations
	Percentage of enterprises in the service sector introducing product or process innovations
	Employment in knowledge-intensive services (KIS) (% of total employment)
	Employment in high and medium-high technology manufacturing (% of total employment)
	Net income from sales of innovative products in industrial enterprises (% of total income)
	Net income from sales of innovative products for export in industrial enterprises (% of total income)

Source: own research based on: *Innovation Union Scoreboard 2014*, pp. 86-90; *Regional Innovation Scoreboard 2009*, p. 7-8; *Regional Innovation Scoreboard 2014*, pp. 8-9.

[1] European Innovation Scoreboard (EIS) until 2009.

The synthetic measure was determined using 4 different construction methods (Table 2) proposed in the literature (Krakowiak-Bal 2005: 72-78), where two methods are based on the distance from the standard (methods with the benchmark) and next two are methods without the benchmark.

Table 2. The innovation index construction methods

Procedure for stimulants			Normalisation formula	Construction method		Values range
Methods without benchmark	Synthetic measure	u_i	$x'_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}}$ (1)	$u_i = \frac{1}{n}\sum_{j=1}^{n} x'_{ij}$ (5)		[0;1]
	Absolut development measure	m_i	$x'_{ij} = \frac{x_{ij}}{s_j}$ (2)	$m_i = \sum_{j=1}^{n} x'_{ij}$ (6)		[0; ∞)
Methods with benchmark	Synthetic measure	s_i	$x'_{ij} = \frac{x_{ij}}{\max x_{ij}}$ (3)	$s_i = \frac{1}{n}\sum_{j=1}^{n} x'_{ij}$ (7)		[0;1]
	Taxonomic development measure	d_i	$x'_{ij} = \frac{x_{ij} - \overline{x}_j}{s_j}$ (4)	$d_i = 1 - \frac{d_{i0}}{d_0}$ (8)	where: $d_{i0} = \sqrt{\sum_{j=1}^{n} (x'_{ij} - \max x'_{ij})^2}$ $d_0 = \frac{1}{n}\sum_{j=1}^{n} d_{i0} + 2s_d$	[0;1]

Note: x_{ij} – value of j-th variable in i-th object (i = 1, …, k; j = 1, …, n), $\overline{x}_j$ – arithmetic mean of j-th variable, s_j – standard deviation of j-th variable, x'_{ij} – standardised value of j th variable in i-th object, n – numer of variables (j = 1, …, n), d_{i0} – Euclidean distance between object i and the standard for variable j, d_0 – critical distance of object i from the standard.

Source: own research based on Krakowiak-Bal (2005: 72-78); Nermend (2009: 36-44); Suchecki (2010: 58-63).

Each method applies a different normalisation procedure: min-max normalisation formula (1), z-score standardisation (4) and quotient transformations with different reference points – standard deviation (2) or maximum value of x_{ij} (3) (Suchecki 2010: 58-59). The construction principles are also different – most of the measures are calculated as a sum or an arithmetic mean of normalised values of input variables (formulas 5, 6, 7). Only in the taxonomic development measure (8) there is a different approach based on the distance between a particular object and the standard, which is a reference object with the maximum value of variable. The values of the measures range from 0 to 1 (and for the absolute development measure, it ranges from 0 to infinity), where values closer to 0 indicate a lower level of innovation and closer to 1 (or higher) – a higher level.

2.2. Results

Table 3 contains values of the aggregate innovation indexes obtained using the 4 different methods presented above. The results indicate that these methods give quite similar results, as the arrangement of the provinces according to each measure is quite similar.

Table 3. Indicators used in the innovation index

2012	u_i		m_i		s_i		d_i	
	Value	**Position**	**Value**	**Position**	**Value**	**Position**	**Value**	**Position**
Dolnośląskie	0.60	**2**	78.0	**2**	0.72	**2**	0.48	**2**
Kujawsko-Pomorskie	0.29	**11**	59.3	**11**	0.52	**10**	0.20	**10**
Lubelskie	0.36	**6**	63.7	**6**	0.58	**6**	0.26	**6**
Lubuskie	0.23	**14**	56.3	**14**	0.47	**15**	0.16	**14**
Łódzkie	0.35	**7**	62.2	**7**	0.57	**7**	0.23	**9**
Małopolskie	0.51	**3**	73.0	**3**	0.68	**3**	0.40	**3**
Mazowieckie	0.74	**1**	87.6	**1**	0.82	**1**	0.50	**1**
Opolskie	0.29	**12**	58.9	**12**	0.51	**12**	0.16	**13**
Podkarpackie	0.32	**9**	61.2	**9**	0.54	**9**	0.23	**8**
Podlaskie	0.32	**8**	61.4	**8**	0.51	**11**	0.18	**11**
Pomorskie	0.46	**4**	71.6	**4**	0.66	**4**	0.38	**4**
Śląskie	0.46	**5**	69.8	**5**	0.62	**5**	0.37	**5**
Świętokrzyskie	0.23	**15**	55.7	**15**	0.47	**14**	0.14	**15**
Warmińsko-Mazurskie	0.12	**16**	49.1	**16**	0.40	**16**	0.04	**16**
Wielkopolskie	0.31	**10**	60.8	**10**	0.56	**8**	0.24	**7**
Zachodniopomorskie	0.25	**13**	57.4	**13**	0.48	**13**	0.18	**12**

Source: own calculations.

In order to determine the correspondence between the arrangements of the provinces according to the values of the particular indexes, the Spearman rank correlation coefficient was used (Krakowiak-Bal 2005: 79):

$$r_S = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)}, \tag{9}$$

where: d – differences between the position of i-th object (province) according to selected indexes, n – number of object.

Table 4. Values of the Spearman rank correlation coefficients.

	u_i	m_i	s_i	d_i
u_i	-			
m_i	1	-		
s_i	0.98	0.98	-	
d_i	0.96	0.96	0.98	-

Source: own calculations.

For two indexes – u_i and m_i – there is exactly the same arrangement of the provinces. Additionally, the index s_i gives results highly consistent with other methods, while arrangement by values of the taxonomic development measure is the least compatible with the others.

In further analysis of the regional innovation level, the aggregate index u_i is used.

In the next step, the value of the innovation index u_i for Poland was determined, which allowed for the analysis of the position of particular provinces in relation to the level of innovation in country (Figure 1).

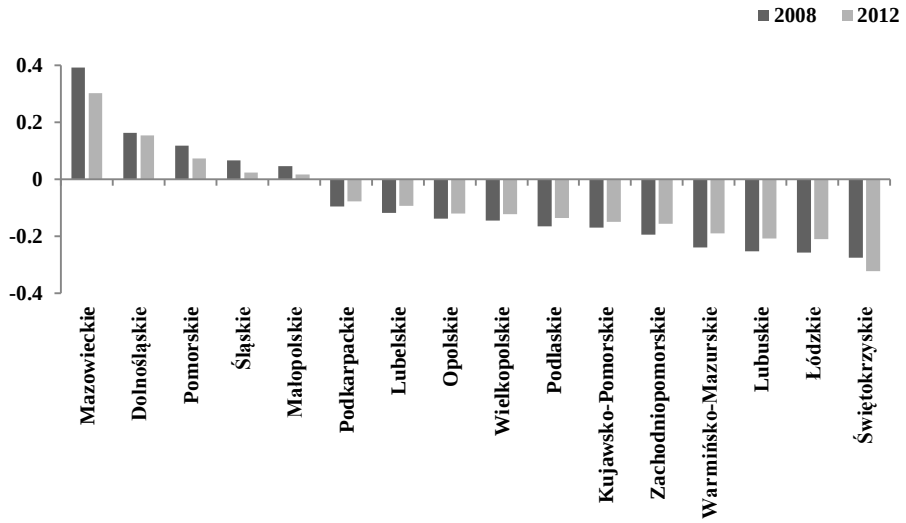

Figure 1. Values of the innovation index in provinces in relation to value for Poland in 2008 and 2012

Source: own calculations.

The group of provinces with innovation index values higher than for Poland between 2008 and 2012 remained the same (Dolnośląskie, Małopolskie, Mazowieckie, Pomorskie and Śląskie), although the order of provinces changed slightly. Also, the group of provinces with index values lower than for Poland is the same in 2008 and 2012, but the shifts between provinces were more

significant there – in 2012 compared to 2008, the positions of Podkarpackie, Opolskie and Warmińsko-Mazurskie significantly decreased, while the Łódzkie province shifted to a higher position.

The analysis of the innovation index in the provinces over the whole period (2008–2012) indicates that there is no clear tendency in the index value changes. What is more, a comparison of the index values from 2008 and 2012 shows that innovation level decreased in most of the provinces. Only in four provinces – Łódzkie, Podlaskie, Lubuskie and Świętokrzyskie – the values of the innovation index did increase during the analysed period.

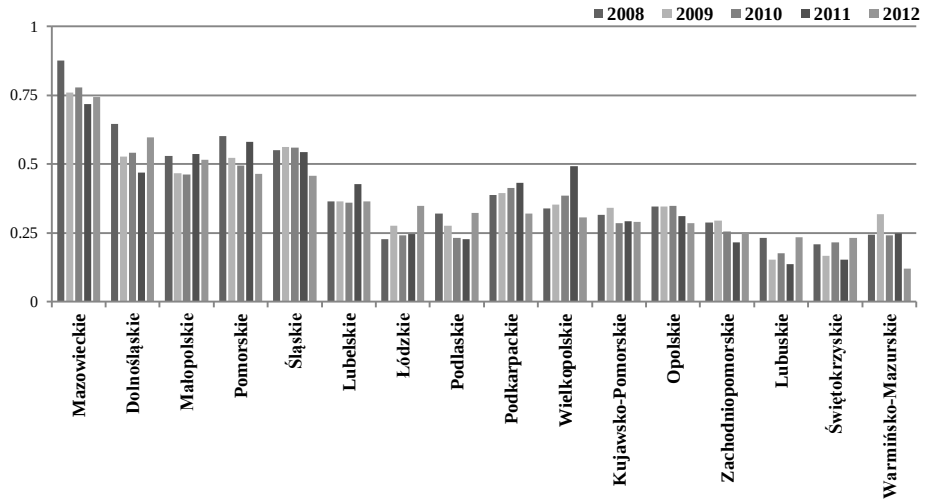

Figure 2. Innovation level in provinces over the years 2008–2012

Source: own calculations.

Dividing the provinces into four groups characterised by a similar level of innovation (Figure 3) using a technique based on the arithmetic mean and standard deviation (Czupich 2009: 40) confirms a slight decrease in innovation level between 2008 and 2012.

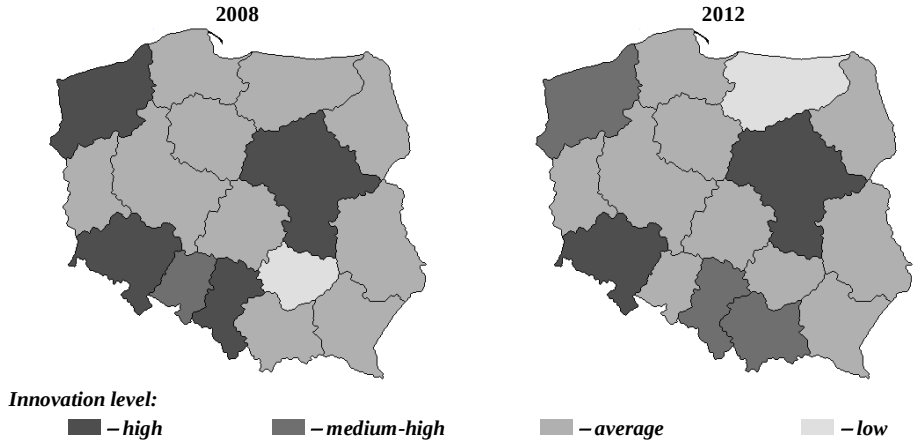

Figure 3. Innovation level in the provinces in 2008 and 2012

Source: own calculations.

3. INNOVATION LEVEL AND REGIONAL DEVELOPMENT

The last element of the research was an analysis of the relationship between the innovation level, as measured by an aggregate innovation index, and regional development as expressed by GDP per capita.

A scatter plot of values of the innovation index and GDP per capita (Figure 4) implies a positive association between these two characteristics: low values of the innovation index correspond with low values of GDP per capita and, similarly, high values of these characteristics also correspond to each other. In 2011, four groups of provinces could be extracted. The first group included provinces with relatively low values of both the innovation index and GDP per capita (Łódzkie, Zachodniopomorskie, Kujawsko-Pomorskie, Opolskie, Warmińsko-Mazurskie, Podlaskie, Świętokrzyskie and Lubuskie). The second group with Dolnośląskie, Śląskie, Wielkopolskie, Pomorskie and Małopolskie, was characterised by average innovation and regional development levels. The third group included the Lubelskie and Podkarpackie provinces with low values of GDP per capita and an average level of innovation (but much higher than the development level). There was also one outlier – the Mazowieckie province – that was characterised by a high level of both innovation and socio-economic development.

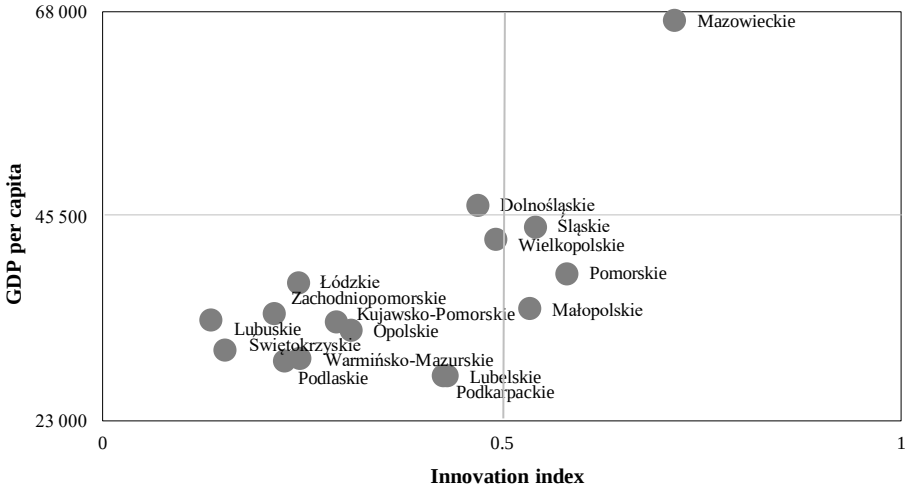

Figure 4. Interdependence between innovation and GDP per capita in 2011

Source: own calculations.

In order to confirm the statistical relationship between the innovation level and GDP per capita linear correlation coefficient was used. Values of the coefficients calculated for particular years of analysis are presented in Table 5.

Table 5. Values of the Pearson's linear correlation coefficients

		Innovation level			
		2008	**2009**	**2010**	**2011**
GDP per capita	**2008**	**0.76**	0.74	0.77	0.64
	2009	0.78	**0.75**	0.78	0.66
	2010	0.79	0.76	**0.79**	0.66
	2011	0.80	0.78	0.81	**0.68**

Source: own calculations.

All the correlation coefficients from the analysed period are positive and greater than the critical value $r^* = 0.497$ (at the 5% level of significance and n-2 degrees of freedom) calculated using the following formula:

$$r^* = \sqrt{\frac{(t_{\alpha,n-2})^2}{(t_{\alpha,n-2})^2 + n - 2}}, \tag{10}$$

where: $t_{\alpha,n-2}$ – value of the Student's t-distribution, n – number of object.

The values of Pearson's linear correlation coefficients indicates that changes in the innovation and regional socio-economic development level proceed

in the same direction – an increase in the level of innovation goes with GDP per capita growth (or a decrease in innovation level goes with a decline in the value of GDP per capita). The results confirm a relatively strong, positive and statistically significant relationship between the level of innovation and regional development.

4. CONCLUSIONS

The results of the analysis indicate that various taxonomic methods of constructing synthetic measures give similar results, as the arrangement of provinces according to each measure was similar. Nevertheless, the taxonomic measure of development gave results least consistent with other methods.

The group of provinces with the highest value of innovation index in 2012 include Dolnośląskie, Małopolskie, Mazowieckie, Pomorskie and Śląskie, and is the same as in 2008.

The analysis of the innovation index in the provinces in the period from 2008 to 2012 indicates that there is no clear tendency in innovation level changes. What is more, a comparison of the index values from 2008 and 2012 shows that innovation level decreased slightly in most of the provinces and in Poland in general.

An analysis of the relationship between the innovation level, measured by an aggregate innovation index, and the regional development, as expressed by a GDP per capita, confirms a positive association between these two characteristics. There is also relatively strong and statistically significant relationship between innovation level and the provinces' level of socio-economic development.

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ABSTRACT

The paper presents issues of measuring regional innovation level with the use of synthetic measures constructed on the basis of selected taxonomic methods.

The synthetic measure was determined with the use of 4 different construction methods, where two methods are based on the distance from the standard (methods with the benchmark) and next two are methods without the benchmark. Each method applies a different normalisation procedure. Also principles of measures construction are different. Selection of 17 variables used in an aggregate index was based mainly on the indicators used in the *Innovation Union Scoreboard* and *Regional Innovation Scoreboard*.

The last part of the article contains an analysis of the relationship between the innovation and regional development level over time. 16 Polish provinces were studied in the period from 2008 to 2012.

INNOWACYJNOŚĆ REGIONALNA A ROZWÓJ SPOŁECZNO-GOSPODARCZY

ABSTRAKT

Głównym przedmiotem zainteresowania w niniejszym artykule są kwestie związane z pomiarem poziomu innowacyjności regionalnej za pomocą miar syntetycznych skonstruowanych z wykorzystaniem wybranych metod taksonomicznych.

W badaniu skonstruowano agregatowy indeks innowacyjności z wykorzystaniem czterech różnych metod wyznaczania miar syntetycznych: dwóch zaliczanych do metod wzorcowych oraz dwóch metod bezwzorcowych. Każda z zastosowanych metod bazuje na innej procedurze normalizacji zmiennych a miary syntetyczne wyznaczane są według rożnych formuł. Do budowy agregatowego indeksu innowacyjności wykorzystano 17 mierników cząstkowych, przy wyborze, których wzorowano się głównie na wskaźnikach publikowanych w ramach *Innovation Union Scoreboard* oraz *Regional Innovation Scoreboard*.

W końcowej części artykułu przeprowadzona została analiza zależności pomiędzy poziomem innowacyjności a poziomem rozwoju poszczególnych regionów w czasie. Badanie przeprowadzono dla 16 województw Polski w okresie od 2008 do 2012 roku.