Economic development of Polish voivodeships in the years 2010-2014. Application of taxonomic measure of development with entropy weights

Michał Bernard Pietrzak [1], Adam P. Balcerzak [2]

Abstract

Implementing policy and forming socioeconomic conditions that support sustainable and equable growth of regions is currently an important objective both at European and national level. Regional development policy is supported by significant resources from European Union funds. As a result, a constant monitoring of the development process at regional level with application of quantitative methods is an important scientific and practical task. Thus, the aim of the article is to assess the level of economic development in Poland at the voivodeships level (NUTS 2). Economic development is considered here as a multiple-criteria phenomenon. In the case of multiple-criteria analysis a common dilemma is attributed to the problem of applying appropriate weights for variables used in the research. Therefore, in order to provide a rating of voivodeships a taxonomic measure of development with entropy weights was applied here. The research was conducted for the years 2010-2014. It was based on the data provided by Central Statistical Office of Poland. The results of the analysis confirm that in spite of a progress obtained by all voivodeships significant disparities between them are still present.

Keywords: *entropy weighs, multiple-criteria decision analysis, taxonomic measure of development, regional development*

JEL Classification: O18, P25, C38

1 Introduction

The main empirical objective of the article is to assess the level of economic development in Poland at the voivodeships level (NUTS 2) in the years 2010-2014. Currently it is commonly accepted that a single measure of economic development or welfare – especially the most commonly used one such as GDP per capita – provides oversimplified information on the subject. The phenomenon should be considered as a complex and multivariate problem. As a result in the research a multiple-criteria decision analysis tools are applied. For this purpose a taxonomic measure of development based on the method proposed by Hellwig will be used, where for proposing weights for given aspects entropy values are applied.

In the research the following hypothesis is given: In Poland one can see the process of improvement in the level of economic development at regional level.

[1] Corresponding author: Nicolaus Copernicus University/Department of Econometrics and Statistics, ul. Gagarina 13a, 87-100 Toruń, Poland, e-mail: michal.pietrzak@umk.pl.
[2] Nicolaus Copernicus University/Department of Economics, e-mail: adam.balcerzak@umk.pl.

2 Taxonomic measure of development: methodology

The problem of economic development must be considered as a multivariate phenomenon that can be characterised with many economic aspects (Pietrzak et al., 2013; Balcerzak, 2016a, 2016b; Balcerzak and Pietrzak, 2016; Jantoń-Drozdowska and Majewska, 2016; Łyszczarz, 2016; Małkowska and Głuszak, 2016; Pietrzak, 2016). In order to model and measure such phenomenon one can use taxonomic measure of development (*TMD*) that was originally proposed by Hellwig (see also: Balcerzak, 2016b; Balcerzak and Pietrzak, 2016).

In the case of multiple-criteria decision analysis problems a researcher usually faces a dilemma concerning the potential differences in the importance of given aspects (specific variables) and thus differences in their influence on the analyzed phenomenon. In order to solve that problem a set of different weights for each variable can be used, where normalized variables are multiplied by weights in the process of obtaining taxonomic measure of development (Balcerzak and Pietrzak, 2016c; Żelazny and Pietrucha, 2017). In the case of current research the objective weights based on the entropy values are used (see: Wang and Lee, 2009). In the procedure the definition of Shannon entropy prosed and developed in the context of information theory is applied.

The procedure of assessing *TMD* based on Hellwig method with application of entropy weights is given in the following steps (Balcerzak and Pietrzak, 2016):

1. A selection of a set of object O_i (i=1,2,..., m) and diagnostic variables X_j (j=1,2,.., n) for a given economic phenomenon.
2. Assessing a set of entropy weights w_j for variables X_j based on the entropy value (see: Wang, Lee, 2009). In the case of the current research the proposed procedure of assessing entropy weights with application of Shannon entropy is extended by the authors with the time dimension. In the first step the entropy value e_{jt} is assessed (equation 1).

$$e_{jt} = -\frac{1}{\ln(m)} \sum_{i=1}^{m} p_{ijt} \ln(p_{ijt}) \quad , \quad p_{ijt} = \frac{x_{ijt}}{\sum_{i=1}^{m} x_{ijt}} \tag{1}$$

In the next step, based on the obtained values, entropy weights w_j with the equation 2 are assessed, where the sum of entropy weights w_j is equal to 1.

$$w_{jt} = \frac{1 - e_{jt}}{n - \sum_{j=1}^{n} e_{jt}} \tag{2}$$

3. A normalization of diagnostic variables[3], which enables to obtain a set of normalised diagnostic variables Z_j.
4. Including entropy weights w_j for every normalised diagnostic variable Z_j with equation 3.

$$y_{ijt} = z_{ijt} w_{jt} \tag{3}$$

5. An assessment of a pattern of development x_{ojt} for every diagnostic variable Z_j with equation 4. In the case of dynamic analysis, the arithmetic average values, the values of standard deviation applied for standardisation, and the values of pattern of development are set as constant for the whole analysed period. It is a condition for obtaining a compatibility of the objects in different points in time *t*.

$$y_{0jt} = \max_{it} y_{ijt} \tag{4}$$

6. For every object O_i an assessment of distance to the pattern of development in a given point in time with equation 5.

$$d_{i0t} = \sqrt{\sum_{j=1}^{p} (y_{ijt} - y_{0jt})^2} \tag{5}$$

7. The value of taxonomic measure of development TMD_{it}, which describes the level of development of analyzed phenomenon for every object O_i in time t can be given with equation 6

$$TMD_{it} = 1 - \frac{d_{i0t}}{d_{0t}}, \tag{6}$$

where $d_{0t} = \bar{d}_{0t} + 2s_{dt}$, and $\bar{d}_{0t}$, s_{dt} are given with formula (7).

$$\bar{d}_{ot} = \frac{1}{n}\sum_{i=1}^{n} d_{i0t}, \quad s_{ot} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (d_{i0t} - \bar{d}_{ot})^2} \tag{7}$$

The values of TMD_{it} are on the scale of 0-1, where the high values of TMD_{it} indicate high level of development of a given phenomenon. In recent years an interesting direction of development of the concept of taxonomic measure of development relates to the problem of taking into account spatial interdependence in the design of the measure, which can be found in the works of Pietrzak (2016).

[3] In the current resarch a standarisation of variables based on the arithmetic average value and standard deviation was conducted.

3 Assessment of socio-economic development at regional level in Poland

Based on the aim of the article the values of taxonomic measure of development were assessed for the years 2010 and 2014. The set of diagnostic variables used in the research is given in table 1. The values of the variables were provided by Central Statistical Office of Poland and are available in the service: http://wskaznikizrp.stat.gov.pl/. The set of diagnostic variables can be considered as incomplete. The selection of the variables is based on the conducted literature review devoted to the determinants of growth and economic welfare (Hadaś-Dyduch, 2015; Kordalska and Olczyk, 2016; Kondratiuk-Nierodzińska, 2016; Ciburiene, 2016; Shuaibu and Oladayo, 2016; Kryk, 2016; Zemtsov et al., 2016). However, the authors are aware that the choice of variables given in table 1 can be considered as arbitrary.

Based on the procedure described in previous section the empirical research was started with an assessment of the weights, where the entropy values were used. The results are given in table 2. In the case of all the variables related to different aspects of economic development the weights values close to 0,25 were obtained. As a result it can be said that the influence of all the variables on the TMD_{it} is generally at the same level. What is more the changes in the values of weights between the years 2010 and 2014 are also quite small. Additionally, one can see that there is also a tendency to equate the values of the weights, which can indicate that all the variables tend to have the same importance for economic development in the whole analyzed period.

Economic development	
Area 1 (EO_1) – Economy	
X_1 – Gross domestic product per capita	stimulant
X_2 – Investments outlays per capita	stimulant
Area 2 (EO_2) – Zatrudnienie	
X_3 – Employment rate by age	stimulant
Area 3 (EO_3) – Innowacyjność	
X_4 – Expenditure on R&D activity in relation to GDP	stimulant

Table 1. Diagnostic variables.

Weights (year)			
2010			
w_1	w_2	w_3	w_4
0.248	0.254	0.262	0.236
2014			
w_1	w_2	w_3	w_4
0.251	0.251	0.253	0.245

Table 2. Weights based on the entropy values.

Next the values of TMDit for economic development for the years 2010 and 2014 were assessed. Based on the obtained values of TMDit a ranking of voivodeships for both years was given. Additionally, the voivodeships were grouped into four relatively homogenous subsets, where the voivodeships characterised with the highest level of economic development was classified in the class 4 and the once with its lowest level were grouped in the class 1. For this purpose a natural breaks method was applied. The results are given in table 3 and figure 1.

In the years 2010-2014 the level of economic development in the case of most of the voivodeships was improved, which can be seen in the changes in their grouping. Additionally, an increase in the value of TMDit was obtained. In the year 2010 in the first class grouping the voivodeships with the lowest level of economic development one could find five voivodeships (lubelskie, opolskie, warmińsko-mazurskie, podlaskie, zachodniopomorskie), whereas in the year 2014 only two voivodeships (świętokrzyskie and warmińsko-mazurskie) could be found here. A negative example could be seen in the case of świętkorzystkie voivodeship, which in the first year of analysis was classified in the 2 group, whereas in the year 2014, it was found in the 1 class – characterised with the lowest level of development.

Economic development							
2010				2014			
Voivodeships	TMR	Rank	Class	Voivodeships	TMR	Rank	Class
mazowieckie	0.721	1	4	mazowieckie	1.000	1	4
wielkopolskie	0.417	2	3	wielkopolskie	0.507	2	3
pomorskie	0.347	3	3	dolnośląskie	0.498	3	3
łódzkie	0.344	4	3	pomorskie	0.483	4	3
dolnośląskie	0.333	5	3	łódzkie	0.478	5	3
małopolskie	0.315	6	3	małopolskie	0.434	6	3
śląskie	0.298	7	2	śląskie	0.41	7	3
lubuskie	0.294	8	2	podlaskie	0.339	8	2
świętokrzyskie	0.266	9	2	lubelskie	0.301	9	2
kujawsko-pomorskie	0.254	10	2	opolskie	0.296	10	2
podkarpackie	0.226	11	2	zachodniopomorskie	0.293	11	2
lubelskie	0.205	12	1	kujawsko-pomorskie	0.287	12	2
opolskie	0.192	13	1	podkarpackie	0.279	13	2
Warmińsko-mazurskie	0.169	14	1	lubuskie	0.262	14	2
podlaskie	0.164	15	1	świętokrzyskie	0.202	15	1
zachodniopomorskie	0.146	16	1	Warmińsko-mazurskie	0.166	16	1

Table 3. Ranking and grouping of voivodeships based on the level of economic development.

Mazowieckie voivodeship is the one with the highest level of economic development. Both in 2010 and 2014 it forms individually the 4 class, which is characterised with the highest level of development.

In the 3 class with high level of economic development in the year 2010 one could see dolnośląskie, wielkopolskie, pomorskie, łódzkie and małopolskie voivodeships, whereas in the year 2014 one could additionally find śląskie voivodeship in that group. In the case of the class with an average level of development in the year 2014 one could see zachodniopomorskie, podlaskie, lubelskie, opolskie, kujawsko-pomorskie, podkarpackie and lubuskie voivodeships. Additionally, in the analyzed period a promotion of lubelskie, opolskie, zachodniopomorskie and podlaskie voivodeships form the 1 to 2 class was recorded.

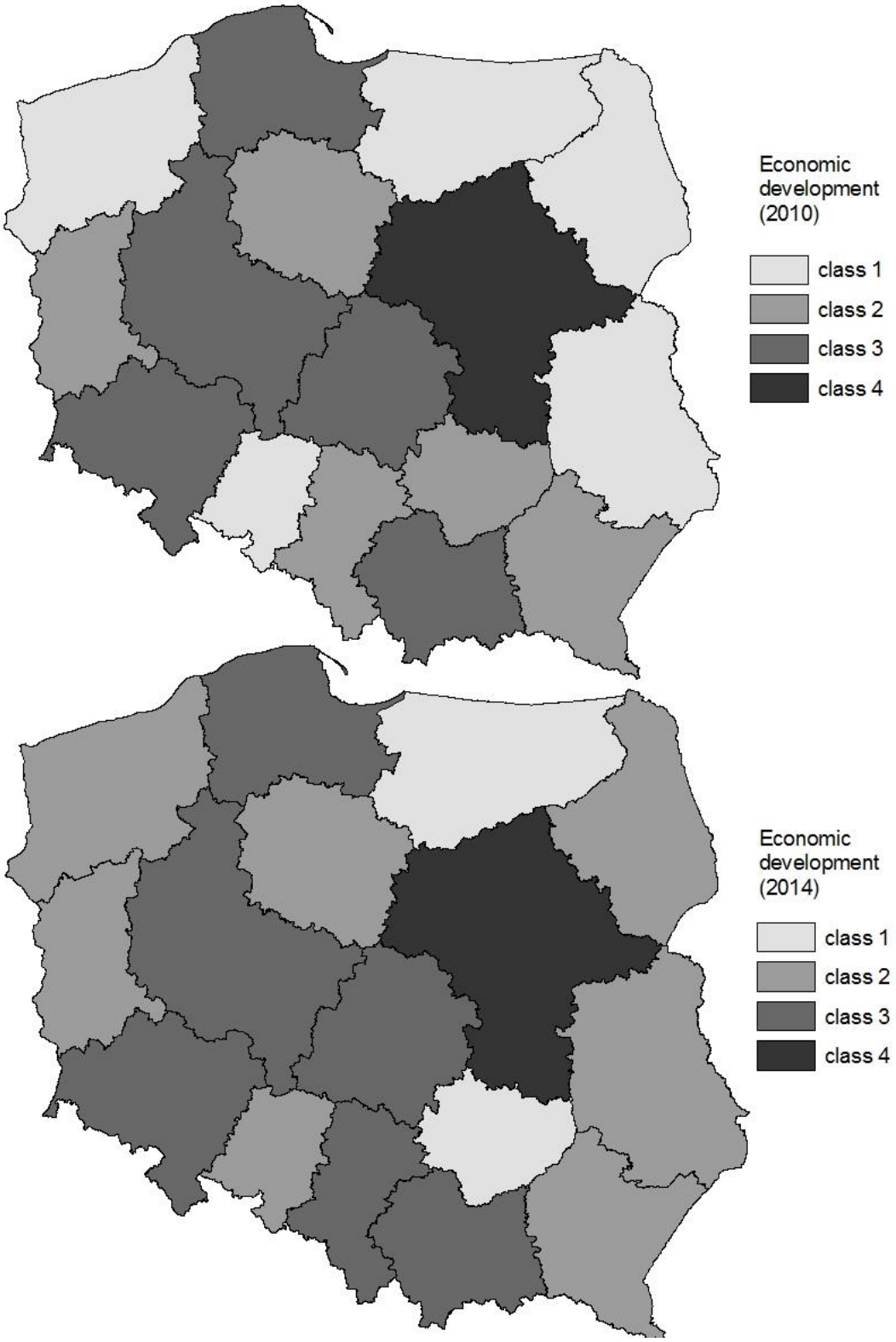

Fig. 1. The level of economic development Poland in the year 2010 and 2014.

Conclusions

The aim of the article was to assess the level of economic development in Poland at the voivodeships level in the years 2010-2014. In the analysis the phenomenon of regional

economic development was considered as a multivariate problem. Thus, a taxonomic measure of development with the weights based on entropy values were applied.

Based on the obtained result, it can be said that the empirical hypothesis of the research given as follow – In Poland one can see the process of improvements in the level of economic development at regional level – was not rejected.

References

Balcerzak, A. P. (2016a). Fiscal Burden in the European Union Countries. *Economic Annals XXI*, 161(9-10), 4-6.

Balcerzak, A. P. (2016b). Technological Potential of European Economy. Proposition of Measurement with Application of Multiple Criteria Decision Analysis. *Montenegrin Journal of Economics*, 12(3), 7-17.

Balcerzak, A. P., & Pietrzak, M.B. (2016). Quality of Institutions for Knowledge-based Economy within New Institutional Economics Framework. Multiple Criteria Decision Analysis for European Countries in the Years 2000–2013. *Economics & Sociology*, 9(4), 66-81.

Ciburiene, J. (2016). The Evaluation of Economic Development Index of Poland and Lithuania in the Context of the European Union. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 11(3), 437-449.

Hadaś-Dyduch, M. (2015). Polish macroeconomic indicators correlated-prediction with indicators of selected countries. In M. Papież & S. Śmiech (Eds.). *Proceedings of the 9th Professor Aleksander Zelias International Conference on Modelling and Forecasting of Socio-Economic Phenomena, Conference Proceedings.* Cracow: Foundation of the Cracow University of Economics, 68-76.

Jantoń-Drozdowska, E., & Majewska, M. (2016). Investment Attractiveness of Central and Eastern European Countries in the Light of New Locational Advantages Development. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 11(1), 97-119.

Kondratiuk-Nierodzińska, M. (2016). New Knowledge Generation Capabilities and Economic Performance of Polish Regions. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 11(3), 451-471.

Kordalska, A., & Olczyk, M. (2016). Global Competitiveness and Economic Growth: A One-Way or Two-Way Relationship?. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 11(1), 121-142.

Kryk, B. (2016). Accomplishment of the European Union Lifelong Learning Objectives in Poland. *Oeconomia Copernicana*, 7(3), 389-404.

Łyszczarz, B. (2016). Public-private Mix and Performance of Health Care Systems in CEE and CIS Countries. *Oeconomia Copernicana*, 7(2), 169-185.

Małkowska, A., & Głuszak, M. (2016). Pro-investment Local Policies in the Area of Real Estate Economics - Similarities and Differences in the Strategies Used by Communes. *Oeconomia Copernicana*, 7(2), 269-283.

Pietrzak, M. B. (2016). The Problem of the Inclusion of Spatial Dependence Within the TOPSIS Method. *Montenegrin Journal of Economics*, 12(3), 69-86.

Pietrzak M. B, Wilk J., & Siekaniec M. (2013). The Impact of Metropolitan Areas on Internal Migrations in Poland. The Case of Southern Regions. In M. Papież & S. Śmiech (Eds.). *Proceedings of the 7th Professor Aleksander Zelias International Conference on Modelling and Forecasting of Socio-Economic Phenomena*. Cracow: Foundation of the Cracow University of Economics, 124-132.

Shuaibu, M., & Oladayo, P. T. (2016). Determinants of Human Capital Development in Africa: A Panel Data Analysis. *Oeconomia Copernicana*, 7(4), 523-549.

Wang, T. C., & Lee, H. D. (2009). Developing a fuzzy TOPSIS approach based on subjective weights and objective weights. *Expert Systems with Applications*, 36(5), 8980-8985.

Zemtsov, S. P., Pavlov, P. N., & Sorokina, A. V. (2016). Specifics of Cluster Policy in Russia. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 11(3), 499-536.

Żelazny R., & Pietrucha J. (2017). Measuring Innovation and Institution: the Creative Economy Index. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 12(1).