Digital economy in Polish regions. Proposal of measurement via TOPSIS with generalized distance measure GDM

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

Abstract

Investing in digital infrastructure and building effective digital economy is currently considered as a basic condition for keeping international competitiveness of developed economies. In the case of developing countries in some economic models it is considered as a factor that can help to avoid middle income trap. From the regional perspective developing digital economy can support the process of convergence and closing development gap between the regions. As a result, a comparative research concerning the development level of digital economy is an important scientific task. In this context, the aim of the article is to assess and compare the development level of digital economy in Polish regions (NUTS 1). The digital economy is commonly considered as a multiple-criteria phenomenon. Thus, an approach based on TOPSIS method with application of generalized distance measure GDM was used in the analysis. Six diagnostic variables concerning digital infrastructure and level of its utilization were used. The research was conducted for the years 2012-2015 with application of Eurostat Data. The conducted analysis confirmed relatively quick progress in the field of building digital economy obtained by Polish regions.

Keywords: *digital economy, multiple-criteria analysis, TOPSIS, generalized distance measure GDM*
JEL Classification: P25, C38

1 Introduction

Supporting development of a digital economy both at national and regional level is currently considered as a basic policy objective for all European governments (Balcerzak, 2016; Ciburiene, 2016; Kondratiuk-Nierodzińska, 2016; Kordalska and Olczyk, 2016; Kryk, 2016; Balcerzak and Pietrzak, 2016a, 2016b; Pietrzak and Balcerzak, 2016a, 2016b; Pohulak-Żołędowska, 2016; Shuaibu and Oladayo, 2016; Zemtsov et al., 2016; Żelazny and Pietrucha, 2017). In the case of countries that face the problem of closing technological and development gap, it can be a factor helping to avoid a middle income trap. From the regional perspective it can support the development of regions that are peripheral both form socio-economic and geographic perspective. In this context the aim of the article is to assess and compare the development level of digital economy in Polish regions (NUTS 1) in the years 2012-2015.

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

The digital economy is often treated as a multiple-criteria phenomenon. As a result, in the research TOPSIS method with application of generalized distance measure GDM is used. In the research a hypothesis stating that in Poland at the regional level an improvement of the level of development of digital economy can be seen.

2 TOSPIS method with generalized distance measure GDM

As it was stated the subject of the research is a multiple-criteria problem. Thus, in the case of regional research it can be analyzed with the application of taxonomic measure of development (*TMD*) method originally proposed by Hellwig (see Balcerzak, 2016). In order to apply this method an analyzed phenomenon is divided into a set of economic aspects, where every separate aspect describes different part of phenomenon under consideration. For every aspect a set of diagnostic variables is chosen, which should describe the aspect. Additionally, the variables should be characterized with high information quality. Next based on the diagnostic variables a synthetic taxonomic measure of development is assessed (Pietrzak et al., 2013; Balcerzak, 2016; Balcerzak and Pietrzak, 2016a; Łyszczarz, 2016; Małkowska and Głuszak, 2016; Pietrzak and Balcerzak, 2016b). The obtained taxonomic measure of development covers the impact of all determinants of a given phenomenon and enables a synthetic assessment of its level. The procedure proposed by Hellwig is based on the comparison of the object to pattern of development (also often named in the literature as a positive ideal solution), which is set based on a maximum value of diagnostic variable in the case of stimulants. This procedure was extended with the proposal of comparing the objects also to anti-pattern of development (named as a negative ideal solution). As a result of this extension TOPSIS method was popularized in the literature (see Balcerzak, 2016; Walesiak, 2016).

A key factor in the case of assessing *TMD* measure is a choice of metric which is used for estimating the distance of the objects from pattern and anti-pattern of development. Generalized distance measure GDM introduced by Walesiak is considered as a metric, which can be applied for the variables measured on the ratio scale, interval scale, the ordinal scale or the nominal scale (see Walesiak, 2016). In the economic research variables based on the ordinal scale are commonly used. In order to use properly that kind of variables in multiple-criteria analysis the application of generalized distance measure GDM is necessary. As a result the main advantage of generalized distance measure GDM is its especially high application universality for the variables measured in different scales.

The procedure of assessing of *TMD* based on TOPSIS method with generalized distance measure GDM is described by Walesiak (2016). The values of generalized distance measure

GDM from pattern of development (GDM_{it}^{P}) and anti-pattern of development (GDM_{it}^{AP}) are assessed with equations 1 and 2 (see Walesiak, 2016)

$$GDM_{it}^{P} = \frac{1}{2} - \frac{\sum_{j=1}^{m}(z_{ijt} - P_{kj})(P_{kj} - z_{ijt}) + \sum_{j=1}^{m}\sum_{\substack{l=1 \\ l\neq i,k}}^{n}(z_{ijt} - z_{ljt})(P_{kj} - z_{ljt})}{2\left[\sum_{j=1}^{m}\sum_{l=1}^{n}(z_{ijt} - z_{ljt})^2 \cdot \sum_{j=1}^{m}\sum_{l=1}^{n}(P_{kj} - z_{ljt})^2\right]^{\frac{1}{2}}}, \quad (1)$$

$$GDM_{it}^{AP} = \frac{1}{2} - \frac{\sum_{j=1}^{m}(z_{ijt} - AP_{kj})(AP_{kj} - z_{ijt}) + \sum_{j=1}^{m}\sum_{\substack{l=1 \\ l\neq i,k}}^{n}(z_{ijt} - z_{ljt})(AP_{kj} - z_{ljt})}{2\left[\sum_{j=1}^{m}\sum_{l=1}^{n}(z_{ijt} - z_{ljt})^2 \cdot \sum_{j=1}^{m}\sum_{l=1}^{n}(AP_{kj} - z_{ljt})^2\right]^{\frac{1}{2}}} \quad (2)$$

where $i,l = 1,\ldots,n$ – number of the object, k – number of pattern of development and anti-pattern of development, $j = 1,\ldots,m$ – number of variable, Z_{ijt} – normalized diagnostic variable, P_j – pattern of development, AP_j – anti-pattern of development.

The GDM measure given in equation 1 and 2 should be applied for the variables measured on the interval scale or the ratio scale. There is also a version of GDM measure for the variables measured on the ordinal scale (Walesiak, 2016).

3 Assessment of level of digital economy in Poland at regional level

The empirical aim of the article was to assess the level of development in Poland at NUTS 1 level. The research was conducted for the years 2012 and 2015. In the research a set of diagnostic variables suggested by Eurostat as potential measures of digital economy were used (see table 1). The data for the variables is available in the Eurostat service: http://ec.europa.eu/eurostat.

In order to obtain *TMD* for digital economy we applied TOPSIS method with generalized distance measure GDM and constant patterns and anti-patterns of development for both years of the analysis, which was described in the previous section. In the research standardization based on arithmetic average and standard deviation was used. The estimation was conducted in the R-Cran software – Package 'clusterSim', Searching for Optimal Clustering Procedure for a Data Set, R package version 0.45-1.

Digital economy	
X_1 – Individuals who ordered goods or services over the internet for private use	stimulant
X_2 – Individuals who have never used a computer	dis-stimulant
X_3 – Households with access to the internet at home	stimulant
X_4 – Individuals who accessed the internet away from home or work	stimulant
X_5 – Individuals who used the internet, frequency of use and activities	stimulant
X_6 – Households with broadband access	stimulant

Table 1. Diagnostic variables for digital economy.

Digital economy in Polish regions							
	2012				2015		
Region	TMD	Rank	Class	Region	TMD	Rank	Class
Central Region	0.649	1	1	Central Region	0.975	1	1
Southern Region	0.464	2	1	South-western Region	0.928	2	1
Northern Region	0.167	3	2	Southern Region	0.808	3	2
North-western Region	0.135	4	2	North-western Region	0.806	4	2
South-western Region	0.101	5	2	Southern Region	0.733	5	3
Eastern Region	0.030	6	3	Eastern Region	0.649	6	3

Table 2. Ranking and grouping of regions based on the level of digital economy.

Next based on the diagnostic variables given in table 1 the level of digital economy in Polish NUTS1 was assessed. Based on the obtained value of TMD measure a ranking of regions for both years was given. Additionally, based on the natural breaks method, which consists of minimization of variance for objects from the chosen subsets and maximization of variance between the subsets, the regions were grouped to one of three classes, where the 1 class was grouping the regions with highest level of development of digital economy and 3 class the once with its lowest level. The results are given in table 2 and figure 1.

The obtained results indicate that during the analysed period the level of digital economy in Polish regions was significantly improved. It can be seen in the increased values of TMD in

the year 2015 compared to the year 2012. This indicates high dynamics of the process of digitalisation of Polish economy. In this context, it remains an open question what is a maximum saturation point for the economy in terms of digitization?

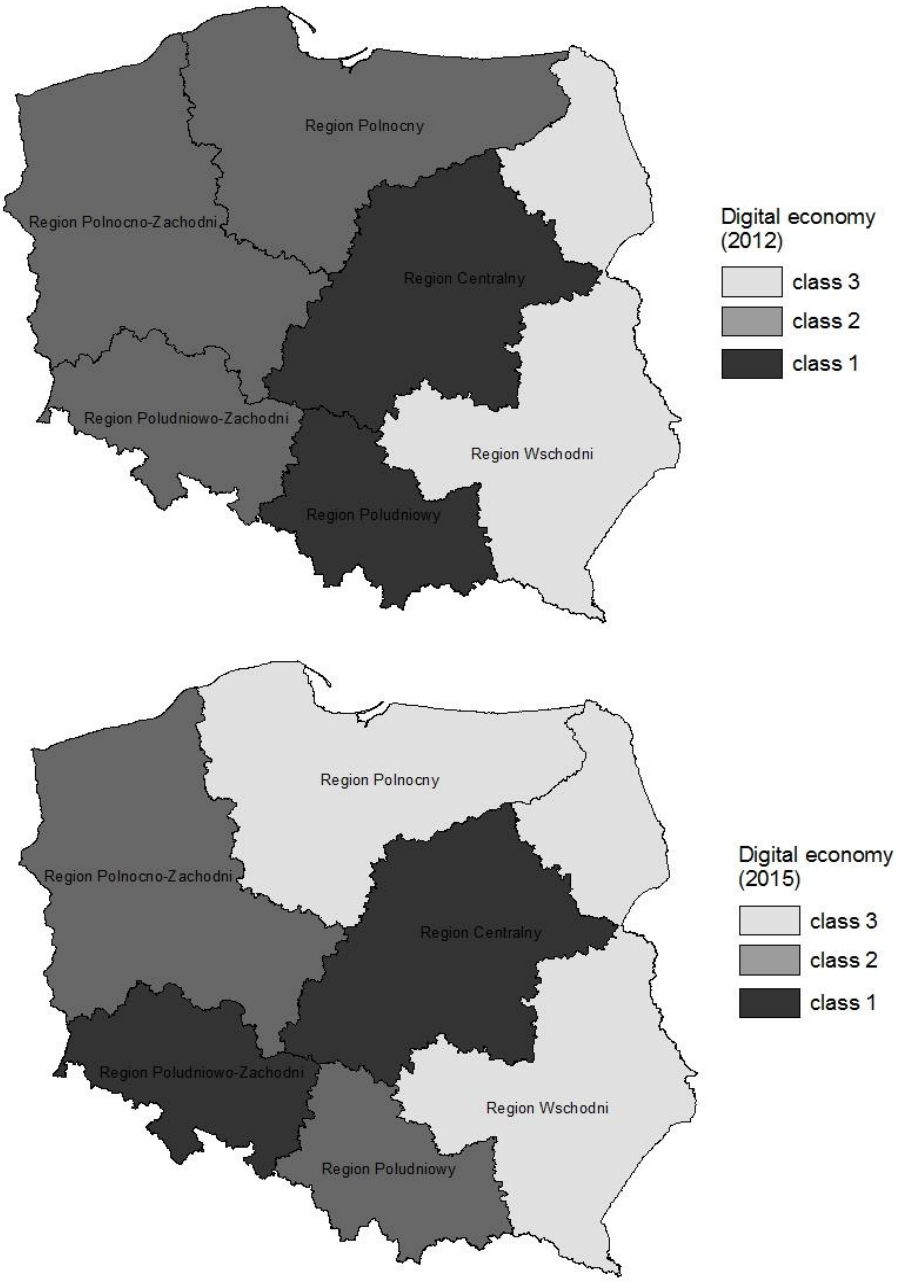

Fig. 1. The level of digital economy in Poland in the year 2012 and 2015.

In the first class grouping the regions with the highest level of digital economy development in the year 2012 one could find Central Region and Southern Region, whereas in the year 2015 these were Central Region and South-western Region. Thus, in both years

Central Region, which covers the most developed form the socio-economic perspective Mazovia Voivodeship with the capital city of the county, is the most digitalised region.

In the 3 class grouping the regions with the lowest level of digital economy development in the year 2012 one could find only Eastern Regions. In the year 2015 in the third class there could be seen two regions Eastern Region and Northern Region.

In the 2 class with average level of analyzed phenomenon in the year 2012 there were: Northern Region, North-western and South-western Regions and in the year 2015 these were two regions: Northern Region and North-western Region. A relatively small increase of the level of TMD for digital economy in the case of Northern Region should be stressed, which in the year 2015 was degraded form the 1 to the 2 class, and relatively quick speed of development of digital economy in the case of South-western Region, which in the year 2015 was promoted from class 2 to 1. These dynamics can confirm that the investment in digital economy can be used by relatively undeveloped regions in order to improve their growth potential in relatively short time.

Conclusions

The research presented in the article was devoted to the multiple-criteria analysis of development of digital economy at regional level in Poland. The research was conducted at NUTS 1 level in the years 2012 and 2015. In the analysis TOPSIS method with application of generalized distance measure GDM was used. The conducted analysis confirmed the research hypothesis, according to which a quick improvement of the level of digital economy in Poland at regional level can be recorded.

The conducted research also shows that the improvements in the case of level of development of digital economy can obtained relatively quickly by less developed regions, which can support their convergence potential with the developed regions.

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