DIGITAL ECONOMY IN CZECH REPUBLIK, SLOVAKIA AND HUNGARY. MEASUREMENT WITH TOPSIS BASED ON ENTROPY MEASURE FOR OBJECTIVE WEIGHTING

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Abstract

Effective digital economy is currently considered as a factor that can help to avoid middle income trap in Central Europe. Supporting the digital economy is considered as an important policy objective both form national and regional perspective. Thus, the objective of the article is to compare the development level of the digital economy in Czech Republic, Slovak and Hungary in the year 2015. The digital economy is defined as a multiple-criteria phenomenon, which is described with diagnostic variables proposed by Eurostat for its measurement at regional level (NUTS 1). In the article TOPSIS method was implemented. In the case of every multiple-criteria analysis tasks a basic dilemma relates to the problem of applying weights for variables used in the research, which should be appropriate for their importance in forming the measured phenomenon. To solve that problem two approaches were applied: a) the TOSPIS method with equal weights for all the variables was used; b) the TOPSIS method was extended with Shannon entropy and objective weights concept. The obtained results confirm disparities between the regions in the analyzed part of Central Europe and the importance of habits and human capital in the process of utilizing potential of the digital economy.

Key words: digital economy, multiple-criteria decision analysis (MCDA), TOPSIS, Shannon entropy, objective weights

JEL Code: P25, C38

Introduction

After almost three decades since the beginning of transformation process Central European economies face the problem of implementing effective policy for sustainable regional development and avoiding middle income trap (Pietrzak *et al.*, 2014). The experiences of the countries that managed to obtain success in these spheres show that building effective digital economy can be an important factor helping to reach these goals. It can be helpful in improving situation on the local labor markets (Müller-Frączek & Pietrzak, 2011; Pietrzak *et al.*, 2013; Murawska, 2016), support effectiveness of policies of local authorities in improving conditions for business and entrepreneurship (Czaplak, 2016; Ambroziak, 2016), and significantly improve international competitive potential of regions and countries (Pietrzak & Łapińska, 2015). Without success in these spheres it is not possible to build effective knowledge based economy as the source of highest value added both at national and regional level (Żelazny & Pietrucha, 2017; Furková & Chocholatá, 2017).

In this context the main objective of the article is to compare the development level of the digital economy in Czech Republic, Slovakia and Hungary in the year 2015. In the research the digital economy is understood as a multiple-criteria phenomenon, which justifies application of multiple-criteria decision analysis (MCDA) tools. In that case TOPSIS method was used. The second aim of the article relates to the problem of proper choice of weights for diagnostic variables applied in the study. As a result the methodological objective of the paper is to compare two approaches: standard TOSPIS approach with equal weights for all the variables and the TOPSIS method extended with Shannon entropy and objective weights concept. The research was conducted at regional level (NUTS 1). It was based on Eurostat data.

1 Methodology

A common problem in economic research relates to the need for analyzing and quantifying phenomena that have multivariate character (Łyszczarz, 2016; Małkowska & Głuszak, 2016; Balcerzak, 2016a). TOPSIS method can be pointed as a tool widely applied for that purpose (see Hwang & Yoon, 1981; Pietrzak, 2016; Balcerzak, 2016b). The method enables to obtain a synthetic measure, which describes a given multivariate problem. In order to obtain the measure a given phenomenon is broken down into a set of economic aspects, where every aspect describes a different part of the phenomenon under research. For each aspect a set of diagnostic variables is selected, which characterizes the selected aspect and allows its description. Then, based on the diagnostic variables, a measure of development for the phenomenon is defined as a synthetic variable. In order to obtain this synthetic measure, for each object diagnostic variables are compared to positive and negative ideal solutions.

In the case of every multiple-criteria decision analysis a basic dilemma relates to the problem of applying weights for variables used in the research, which should be appropriate for their importance in forming the measured phenomenon. From the practical perspective the most common approach is based on the application of equal weights for all the variables, as it enables to avoid arbitral choice of the researcher. However, the problem of arbitral definition of the values of weights can be also solved with application of objective weights, which can be based on the entropy weights (see Wang & Lee, 2009; Shemshadi *et al.*, 2011). In the case of that procedure the definition of Shannon entropy, which was developed and implemented in the information theory, can be applied (see: Shannon & Weaver, 1947).

In order to assess a set of entropy weights w_j for variables X_j based on the entropy value in the first step the entropy value e_{jt} is given (1) (see: Wang, Lee, 2009).

$$e_j = -\frac{1}{\ln(m)} \sum_{i=1}^{m} p_{ij} \ln(p_{ij}) \quad (1) \text{ ; where: } \quad p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (2)$$

Then, based on the obtained values, entropy weights w_j with the equation 3 are assessed.

$$w_j = \frac{1 - e_j}{n - \sum_{j=1}^{n} e_j} \quad (3)$$

Where the sum of entropy weights w_j is equal to 1.

In the next step in order to obtained synthetic measure of development the diagnostic variables should be normalized, which allows to obtain a set of normalized diagnostic variables Z_j. The dis-stimulants should be transferred into stimulants. Equation 3 allows to include entropy weights w_j for every normalized diagnostic variable Z_j. In the case of standard TOPSIS approach with equal weights w_j is defined as equal for all the variables.

$$y_{ij} = z_{ij} w_j \quad (3)$$

Then, positive (y_{wj}) and negative (y_{aj}) ideal solutions can be pointed with equations (5)

$$y_{wj} = \max_i y_{ij} \quad , \quad y_{aj} = \min_i y_{ij} \quad (5)$$

After obtaining ideal solutions it is possible to assess their distances to every object O_i.

$$d_{wi} = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_{wj})^2} \quad , \quad d_{wi} = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_{wj})^2} \quad (6)$$

The value of measure of development TMD_{it}, which synthetically describes the level of development of the phenomenon under research for every object O_i is given with formula 7.

$$TMD_i = 1 - \frac{d_{wi}}{d_{ai} + d_{wi}} \quad (7)$$

The values of the obtained measure are normalized and are on the scale of 0-1, where its high values indicate high level of development of an analyzed phenomenon.

2 Assessment Digital Economy in Czech Republic, Slovakia and Hungary

1.1 Diagnostic variables and data

Digital economy is commonly identified with the development and proliferation of Internet as the main tangible technical infrastructure. However, resent years confirmed that the intangible factors such as ability to use and common habits of potential Internet users are as important as the development of tangible infrastructure. Thus, the phenomenon of digital economy should be treated as multivariate phenomenon. As a result, in the current research the variables relating to both aspects are given in table 1. The data was obtained from the Eurostat service (http://ec.europa.eu/eurostat). It was aggregated at NUTS 1 level.

Tab. 1: Diagnostic variables for digital economy

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

Source: own work.

In the case of variable X_2 the government policy should aim at decreasing its values as it is treated as dis-stimulant. The variables X_1 and X_5 can provide information on the utilization of computers and Internet in the everyday life of society. Thus, they should be treated as stimulants. The same is applied to variables X_3, X_4 and X_6 as they describe the availability level of digital economy infrastructure.

1.2 Results

In the research the measurement of digital economy for Czech Republic, Slovakia and Hungary at regional (NUTS 1) level was conducted. Based on the aim of the article the measure of development of the phenomenon was assessed for the year 2015.

For every diagnostic variable entropy weights were assessed. The results are presented in table 2. The highest values of weights were obtained for X_1 and X_2 variables, which relate to the quality of human capital and the abilities of people to use potential of digital economy. The values of the weights are equal to 0.219 and 0.583 respectively. This result confirms the importance of investment in quality of human capital and it can indicate the potential role of government policy in this regard. The remaining variables have lower, but still significant weights in forming the digital economy. As a result, in the research two approaches were implemented. In the first approach equal weights for all the variables were used. In the second one, the weights given in table 2 were applied.

Tab. 2: Entropy weights w_j

Variable	X_1	X_2	X_3	X_4	X_5	X_6
w_j	0,219	0,583	0,031	0,088	0,043	0,035

Source: own estimation.

For both approaches the ranking of regions was proposed. Additionally, with application of natural breaks method the regions were classified to one of three classes, where in the first class the regions characterized with the highest level of the digital economy development were found. In the third class the regions with its lowest level were grouped. The result are given in table 3 and figure 1.

The obtained results confirm disparities between the analyzed NUTS1 regions. As a result, in spite of a quick development of the digital economy infrastructure, the significant differences in regard to obtained measure confirm visible spatial differences between the regions.

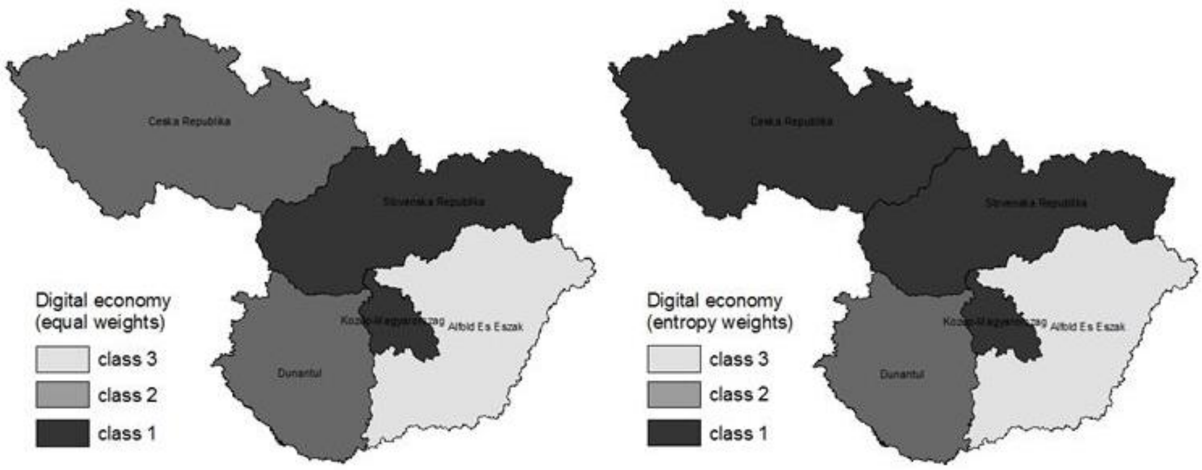
Tab. 3: Ranking and grouping of regions based on the level of digital economy

equal weights				entropy weights			
Region	TMR	Rank	Class	Region	TMR	Rank	Class
Közép-Magyarország	0,749	1	1	Czech Republic	0,852	1	1

Slovakia	0,729	2	1	Slovakia	0,762	2	1
Czech Republic	0,592	3	2	Közép-Magyarország	0,758	3	1
Dunántúl	0,461	4	2	Dunántúl	0,460	4	2
Alföld és Észak	0,057	5	3	Alföld és Észak	0,018	5	3

Source: own estimation.

Fig. 1: The level of digital economy in Czech Republic, Slovakia and Hungary



Source: own estimation.

In the case of first approach with equal weight in the first class of regions with the highest level of the digital economy one can find Közép-Magyarország and Slovakia. On the other hand, application of entropy weights improves the situation of Czech Republic. In the case of second approach in the first class there were Czech Republic, Közép-Magyarország and Slovakia. As in the case of both methodologies Közép-Magyarország and Slovakia can be found in the first class. These NUTS 1 regions can be considered as the once with the highest level of development of the digital economy.

In the third class in the case of both methodologies there is only one Hungarian region Alföld és Észak. The value of the measure of the development of the digital economy for the region is significantly lower, which can indicate the problem of digital trap in the region. From the perspective of the concept of regional sustainability, it should be the region of special attention for Hungarian government and future regional development policies.

In the second class indicating average level of relative development in the case of the first methodology there is Czech Republic and Hungarian Dunántúl. In the case of the method with entropy weights only Dunántúl can be found.

Conclusion

The main aim of the article was to compare the level of development of the digital economy in Czech Republic, Slovakia and Hungary in the year 2015 at NUTS 1 level. In the study the digital economy is understood as a multiple-criteria phenomenon. As a result, TOPSIS method in two variants was applied here. In the case of multiple-criteria analysis an important dilemma relates to the problem of applying weights for variables used in the research, which should be appropriate for their importance in forming the measured phenomenon. In that context the second aim of the article related to the problem of proper choice of weights for variables used in the study. To solve that problem standard TOSPIS approach with equal weights for all the variables and the TOPSIS method extended with Shannon entropy and objective weights concept were applied.

As an empirical contribution the conducted research confirmed that the digital economy phenomenon cannot be treated only as a problem of telecommunication infrastructure, but high values of weights obtained for variables, which relate to the intangible factors such as abilities of people to use potential of Internet indicate the importance of policies supporting intangible competence of people. Additionally, the research showed a significant underdevelopment of Hungarian region Alföld és Észak.

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