TYPOLOGY OF THE EU COUNTRIES IN TERMS OF INNOVATION IN THE CONTEXT OF SUSTAINABLE DEVELOP-MENT ASSESSMENT

SOBCZAK E.*, GŁUSZCZUK D.*

** Faculty of Economics, Management and Tourism, Wrocław University of Economics, Poland*

Abstract
The purpose of the study is separating the relatively homogeneous classes of the EU countries in terms of innovation in the context of sustainable development. Sustainable development monitoring is based on a set of systematized indicators in the areas of social, economic, environmental and institutional-political order. Among the numerous observed processes and phenomena, the ones which combine the orders, contributing to coherent devel-opment (integrated order) are of particular importance. Innovation remains one of such characteristics. Its meas-urement in the research on sustainable development is carried out using 6 indicators (share of net revenues on the sales of innovative products in net revenues on total sales, share of human resources in science and technolo-gy as percentage of economically active population, percentage change in labour productivity, expenditure on R&D against GDP, eco-innovation, the number of inventions filed by residents to the European Patent Office per 1 million population). The data collected within their framework (source - Eurostat) were adopted as the basis for the EU countries classification in terms of their capacity to develop and implement innovations. Multidimensional statistical analysis methods, with particular focus on aggregate measures of development, were applied in the assessment. The conducted research resulted in separating the relatively uniform classes of the EU countries in terms of innovation, including the identification of leaders in the analysed years.

Key words: *innovation, sustainable development, aggregate measure of development*

1. Introduction

Integrated order represents, among others, the substantiation of sustainable development. This clarification seems necessary, as it determines the quantification of processes and phenomena responsible for both lasting and consistent economic, social and environmental development. The very concept of sustainable development should be referred to in the category of an idea defining the general direction of process changes characterized by their positive nature, i.e. related to the transition from a less desirable to a more desirable state. Such more desirable state can be approached as a vision, i.e. the situation we wish to achieve in the future. This pattern, however, will keep evolving, because conti-nuity remains the constant feature of development, which means that one can always define a more desirable state than the current one. For this reason it is important to observe the indicators describing orders and mutual relation-ships between them, which justifies the need to search for countries-leaders of sustainable development and its com-ponents (e.g. in terms of innovation which co-creates economic order). The purpose of this article is to assess the innovation level of the European Union countries, using innovation indicators covering national economies, ap-plied in sustainable development monitoring. The classification of the countries is carried out using aggregate measures of development, and also the identification of the EU countries as innovation leaders, moderate innova-tors, modest innovators and non-innovators is performed.

2. Innovation in the system of sustainable development assessment

The concept of sustainable development monitoring is based on the assessment of integrated order components. It covers economic, social (including institutional-political) and environmental (including spatial) (Borys, 2011) order, emphasizing that the target state of each of them may not remain in

contradiction with the others. These relationships are of particular importance while assessing economic changes resulting not only in economic, but also in social and environmental consequences (Michalski et al., 2015). In this perspective, the implementation of sustainable development principles into economic system is of key importance. Innovation can and should sup-port their implementation, however, under certain conditions.

Innovation is perceived as the feature of enterprises or economies and stands for their capacity to develop and implement innovations, including their absorption, combined with active participation in these processes, e.g. by acquiring resources and skills essential for carrying out innovative activities. The measurement of innovation un-derstood in this way is usually performed by defining the number of developed and implemented innovations (Niedzielski, 2011), i.e. "new or significantly improved products (goods or services), or processes, new marketing methods, or new organizational methods in business practice, workplace organization or external relations" (Oslo Manual, 2005). This approach does not take into account the need to balance three crucial systems (economic, environmental and social), nor the nature of introduced changes. Not every new or significantly improved solution has a positive connotation, because innovations can refer to something new, i.e. multi-directional changes in rela-tion to the existing state (progress, regression, neutrality) (Madej, 1970). This observation is particularly important in the process of assessing these innovations which trigger economic, environmental and social changes. Even if it is assumed that innovations result in positive economic effects only, it should not be automatically translated into their environmental and social effects. The solution to this problem can take a twofold form. Firstly, an innovation and the related innovative activity should be subordinated to the criteria of sustainable development . In practical terms it means the reconstruction of the definition of innovation considering the condition of its harmlessness to both environmental and social spheres. Taking this criterion into account, none of the new or significantly im-proved products, processes, or organizational or marketing methods would be recognized as innovations if their implementation resulted in the violation of sustainable development harmony (Białoń, 2012). Both complex and subjective nature of this assessment seems to undermine the sense of its using. Another, better solution is to extend the spectrum of indicators diagnosing innovation with features and/or their relationships describing the capacity presented by entities (economies) to develop and implement innovations which affect both environmen-tal and social orders in a positive way. This concept covers e.g. a group of eco-innovation indicators characterizing new or significantly improved solutions for the benefit of air, water, soil, flora and fauna protection, etc. This op-tion was adopted in public statistics.

3. Methodology and Data

The diagnosis of innovation in the context of sustainable development assessment is based on the set of six indi-cators which describe (Central Statistical Office, 2018): X1 – share of net revenues on the sales of innovative prod-ucts in net revenues on total sales, X2 – human resources in science and technology (%), X3 – labour productivity (%), X4 – expenditure on R&D against GDP (%), X5 – eco-innovation (EU=100), X6 – the number of inventions filed by residents to the European Patent Office per 1 million population.

The methods of their value measurement and their importance for sustainable development are presented in Tab. 1.

Table 1: Innovation indicators in economic order and sustainable development measurement

Indicator	Value measurement method	Importance for sustainable development
X_1	Share of net revenues on the sales of new and significantly improved products launched on the market in the recent three years in net revenues on total sales.	The degree of enterprise innovation. The level of economy innovation. The saturation of economy with innovative products boosts its competitiveness and creates basis for sustainable development.
X_2	Share of human resources in science and technology as percentage of economically active population aged 25-64.	Human resources for science and technology create the potential for stimulating the innovative capacity of economy.
X_3	Percentage change in labour productivity in the analysed year against previous year. Labour productivity is measured by the value of gross domestic product at fixed prices per unit of workload, i.e. per 1 hour worked.	The pace of changes in labour productivity is correlated with the dynamics of economic development. The level of labour productivity represents economic growth factor and determines economy competitiveness.
X_4	The total amount of internal expenditure incurred on research and development by all entities in the country conducting this activity, regardless of the source of funds, against GDP.	Research and development activity is translated into the technological level of economy, and thus affects socio-economic development to a great extent. X_4 shows the scale of GDP redistribution in the activities aimed at transforming economy towards a knowledge-based economy. R&D expenditure offers the opportunity to change the direction of particular economy sectors' development by implementing innovative and socially desirable solutions, e.g. pro-ecological, less energy- or material-intensive ones, and also by developing technologies friendly for people and protecting their health.
X_5	The indicator is based on 16 indicators from five areas: 1) expenditure (government expenditure on R&D in terms of environment and energy against GDP, share of employment in R&D in total employment, value of early-stage green investments), 2) activities (carried out by an enterprise implementing eco-innovations improving material and energy efficiency and having ISO 14001 certification), 3) results (patents, publications, media information on eco-innovation), 4) environmental effects of implementing eco-innovations (efficiency of energy, raw materials, water use and greenhouse gas emissions),	Eco-innovations limit harmful impacts of economic processes on the environment. Ecological innovations result in cost reductions and rational use of natural resources. Eco-innovations allow not only competitive position strengthening but also establishing a strong position on the market. Eco-innovations contribute to the elimination of unfavourable, man-made changes in the environment.

Indicator	Value measurement method	Importance for sustainable development
	5) socio-economic effects of implementing eco-innovations (the development of "eco-industries" in economy measured as percentage of workforce, share of exports of eco-innovative products in total exports and turnover in eco-industries). The overall result of the EU Member State is calculated as weighted average of 16 sub-indicators (partial indicators). It shows the level of eco-innovation in individual Member States against the EU average, compared to 100 (EU indicator = 100).	
X_6	The number of inventions filed by residents of particular countries for protection in the European Patent Office (EPO) according to the partial calculation method per 1 million inhabitants of a given country.	Developing new solutions determines sustainable economic development by affecting the quality of life while protecting natural resources.

Source: Authors' compilation based on (Central Statistical Office, 2018).

The above listed innovation indicators can be systematized in three groups by arranging them according to orders and mutual relations between them. The first group covers these indicators which create the basis for formulating valuation judgments about the occurring changes in the area of economic order (X_1, X_2, X_3). The second group includes indicators diagnosing the phenomena and processes in the economic area, which simultaneously influence the environmental order (X_5), whereas the third group lists measures assessing economic order and, at the same time, influencing both environmental and social order (X_4, X_6).

The statistical information necessary to quantify the innovation level of the 28 European Union countries, in the context of sustainable development, comes from the Eurostat database. The research period covers the years 2008 and 2017. Due to the absence of available statistical data the values of X_1 indicator come from the years 2008 and 2012, X_2 indicator from 2010 and 2017, whereas X_6 from 2008 and 2014.

The empirical analysis was carried out in accordance with the following stages of the research procedure (Hellwig, 1968; Walesiak, 2006):

1. The selection of innovation indicators used to monitor sustainable development.
2. Linear ordering of the European Union countries in terms of innovation development level, in the context of sustainable development, using aggregate measures of development.
3. The assessment of the indicator values' diversification and the innovation development level in the EU countries, using basic descriptive parameters, in the years 2008 and 2017.
4. The classification of the European Union countries in terms of innovation level development in the context of sustainable development in the years 2008 and 2017.

Due to the fact that all identified innovation indicators are stimulants (the increase in indicator values results in the increase of innovation level in the context of sustainable development), the normalization formula presenting the following form was used:

$$z_{ij} = \frac{x_{ij}}{\max_i x_{ij}} \quad (1)$$

where: z_{ij} – normalized value of *j*-th indicator in *i*-th country, x_{ij} – value of *j*- th indicator in *i*-th country.

The method of average standardized sums was used as the aggregating function of normalized indicator values:

$$AMI_n = \frac{1}{m}\sum_{j=1}^{m} z_{ij} \quad (2)$$

m – number of indicators describing a given complex phenomenon, *n* = 1, 2,..., *N* number of the country, where: AMI_n,– aggregate measure of innovation level in the context of sustainable development.

Both normalized values of innovation indicators and aggregate measures of development take values in the range [0, 1]. Next, the division of the European Union countries into classes presenting different levels of innovation, in the context of sustainable development, was carried out by specifying the following ranges of aggregate measures values:

Class I – countries characterised by the lowest level of innovation:

$$AMI_n \leq \min_n \{AMI_n\} + \frac{1}{k}R \quad (3)$$

Class II– countries presenting higher innovation level than the ones grouped in class I:

$$\min_n \{AMI_n\} + \frac{1}{k}R < AMI_n \leq \min_n \{AMI_n\} + \frac{2}{k}R$$

(4)

Analogically, the subsequent classes and the last of the identified *k*-th class - countries with the highest innovation level:

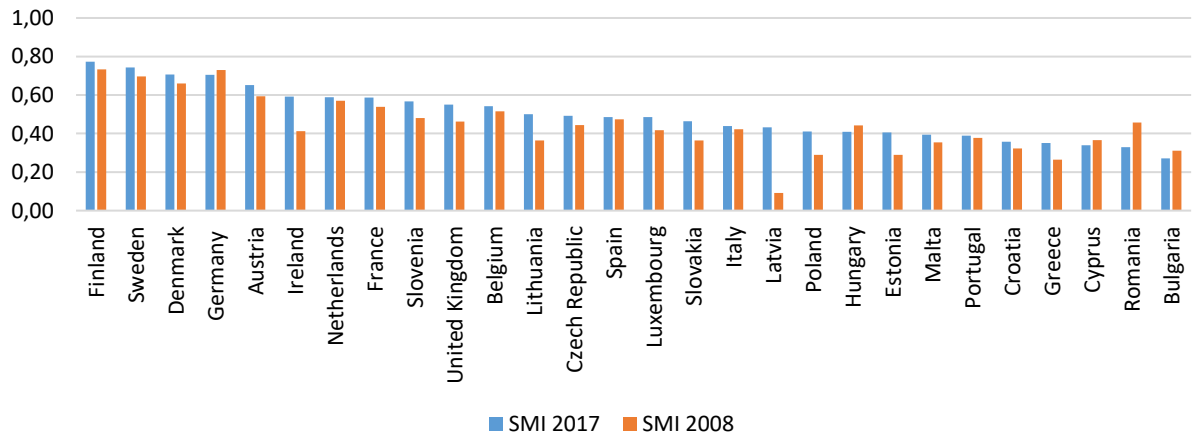
$$\min_n \{AMI_n\} + \frac{k-1}{k}R < AMI_n \leq 1 \quad (5)$$

where: *R* – range of aggregate measure value of the complex phenomenon development, *k* – the number of classes adopted *a priori*.

4. Results and discussion

Fig. 1 shows the linear ordering of the European Union countries, in the years 2008 and 2017, in terms of economy innovation level in the context of sustainable development. The EU countries were ordered by the decreasing values of particular aggregate measures in 2017. The analysis of Fig. 1 shows that Finland recorded the highest level of innovation development in both analysed periods. In Finland the share of R&D expenditure in GDP (3.55% and 2.75%) was very high against the other European Union countries, as well as the share of human resources for science and technology in the economically active population (49.8% and 57.7%), the value of eco-innovation indicator (139 and 141, EU=100) and the number of inventions filed in EPO per 1 million population (238.89 and 341.72). In 2017 the second place, in terms of the innovation development level, was taken by Sweden, where the highest values of four out of six innovation indicators were recorded, including human resources for science and technology (58.6%), expenditure on R&D in GDP (3.25%), eco-innovation (144, EU = 100) and the number of inventions filed in the EPO per 1 million population (350.41).

Figure 1: Linear ordering of the European Union countries in terms of economy innovation level in the years 2008 and 2017



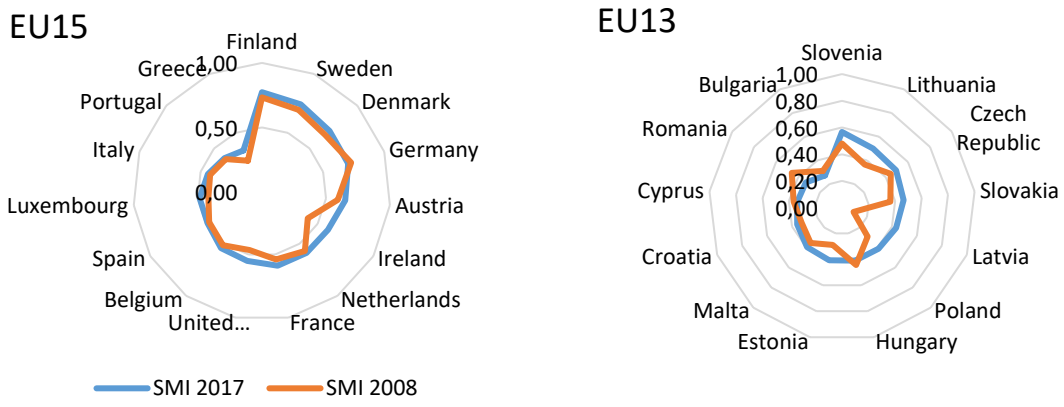
Source: Authors' compilation based on the Eurostat database

The lowest level of innovation development in the context of sustainable development in 2017 was characteristic for Bulgaria, and in 2008 for Latvia. Bulgaria recorded the lowest in the EU share of net revenues from sales of innovative products in net revenues from total sales (4.2 %), the lowest eco-innovation indicator (38, EU=100) and a very small number of inventions filed in EPO per 1 million population (6.55). In Latvia, the first of the analysed periods featured the lowest in the European Union share of net revenues from the sale of innovative products in net revenues from total sales (5.9 %), negative rate of labour productivity changes (-8.8 %) and only 10.39 inventions filed in the EPO for 1 million population.

Fig. 2 presents the values of innovation development measures separately for the EU15 and the so-called countries of the new accession EU13. It can be noticed that in both groups of countries in most cases the values of aggregate measures improved in 2017. However, there occur clear disproportions between the identified groups of countries. The EU15 represent a clearly higher level of innovation development than the EU13, with Greece and Portugal being the exception.

Table 2 presents the descriptive parameters of indicators and aggregate measures regarding innovation development level. The European Union countries, in both analysed periods, featured by far the largest diversification in terms of the number of inventions filed in the EPO per 1 million population. The coefficient of variation was 112.9 % in 2008 and went up to 116.8 % in 2017. In 2008 this indicator was the lowest in Bulgaria (1.62) and the highest in Sweden (303.59). In the subsequent analysed period only 3.43 inventions per 1 million population were reported in Croatia, whereas at the same time 350.41 applications were filed in Sweden. The occurred disproportions in this respect were enormous. In 2017 a large dispersion (95.79 %) was recorded in the rate of changes in labour productivity. In Luxemburg it presented the level of -0.9 % and was the smallest, while in Lithuania an increase was recorded in labour productivity against the previous year by 6.7 %. In 2008 it was impossible to determine the coefficient of variation (negative average value of the indicator).

Figure 2: The values of innovation development measures for the EU15 and the so-called countries of the new accession EU13



Source: Authors' compilation based on the Eurostat database

The smallest diversification of the EU countries in both periods was observed in terms of the share of human resources for science and technology in the economically active population, the coefficient of variation was 19.68 % in 2008 and 18.74 % in 2017, respectively.

The diversification of the EU countries regarding the value of innovation development measure, calculated using the coefficient of variation was 33.55 % in 2008, and in 2017 it went down to 26.8%, which should be assessed as a positive trend.

Table 2: Descriptive parameters of indicators and aggregate measures regarding innovation development level in the European Union countries in 2008 and 2017

Index	Year	Min	Max	Median	V(%)
X_1	2008	5,90 Latvia	18,7 Czech Rep.	12,50	26,59
	2017	4,20 Bulgaria	19,6 Slovakia	10,75	33,67
X_2	2008	23,00 Portugal	51,1 Netherlands	39,75	19,68
	2017	27,70 Romania	58,6 Sweden	48,25	18,74
X_3	2008	-8,80 Latvia	8,2 Romania	-0,10	-
	2017	-0,90 Luxembourg	6,7 Lithuania	1,3	95,79
X_4	2008	0,39 Cyprus	3,55 Finland	1,29	62,44
	2017	0,44 Latvia	3,25 Sweden	1,26	56,14
X_5	2008	31,00 Bulgaria	149,00 Denmark	80,50	42,37
	2017	38,00 Bulgaria	144 Sweden	87,00	31,35
X_6	2008	1,62 Bulgaria	303,59 Sweden	28,98	112,90
	2017	3,43 Croatia	350,41 Sweden	37,33	116,80
AMI	2008	0,09 Latvia	0,73 Finland	0,43	33,55
	2017	0,27 Bulgaria	0,77 Finland	0,49	26,80

Source: Authors' compilation based on the Eurostat database

Table 3 presents the linear ordering and classification of the European Union countries in terms of innovation level in the context of sustainable development. In 2008, due to higher diversification and the occurring disproportions between the EU countries, it was decided to distinguish four classes of the EU countries, and in 2017 the division into three classes was made. In both analysed periods the composition of the class of innovation leaders was identical. Fig. 3 presents the values of aggregate measures for the class of innovation leaders. As it can be noticed, among the listed countries only Germany came out worse in the ranking (from the second position in 2008 to the fourth in 2017).

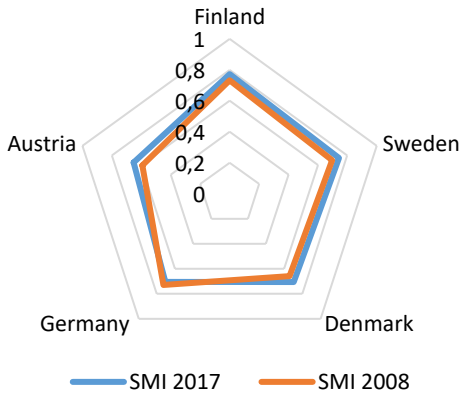
Table 3: Classification of the European Union countries in terms of the level of innovation development in 2008 and 2017

No.	Countries	SMI 2008	No.	Countries	SMI 2017
Class 1: Innovation leaders					
1	Finland	0,732	1	Finland	0,773
2	Germany	0,729	2	Sweden	0,743
3	Sweden	0,697	3	Denmark	0,706
4	Denmark	0,660	4	Germany	0,705

5	Austria	0,593	5	Austria	0,652
Class 2: Moderate innovators					
6	Netherlands	0,570	6	Ireland	0,592
7	France	0,538	7	Netherlands	0,589
8	Belgium	0,515	8	France	0,588
9	Slovenia	0,480	9	Slovenia	0,567
10	Spain	0,473	10	United Kingdom	0,550
11	United Kingdom	0,462	11	Belgium	0,541
12	Romania	0,457	12	Lithuania	0,500
13	Czech Republic	0,444	13	Czech Republic	0,492
14	Hungary	0,443	14	Spain	0,486
15	Italy	0,423	15	Luxembourg	0,486
16	Luxembourg	0,417	16	Slovakia	0,465
17	Ireland	0,412	17	Italy	0,439
Class 3: Modest innovators					
18	Portugal	0,378	18	Latvia	0,433
19	Cyprus	0,365	19	Poland	0,411
20	Lithuania	0,365	20	Hungary	0,409
21	Slovakia	0,363	21	Estonia	0,405
22	Malta	0,354	22	Malta	0,394
23	Croatia	0,323	23	Portugal	0,389
24	Bulgaria	0,311	24	Croatia	0,358
25	Estonia	0,289	25	Greece	0,351
26	Poland	0,289	26	Cyprus	0,339
27	Greece	0,265	27	Romania	0,329
Class 4: Non-innovators			28	Bulgaria	0,271
28	Latvia	0,092	-		

Source: Authors' compilation based on the Eurostat database

Figure 3: Aggregate measure values of innovation development for the European Union countries included in the class of innovation leaders in 2008 and 2017



Source: Authors' compilation based on the Eurostat database

Class 2 is the most numerous since it includes 12 countries assessed as moderate innovators. The compositions of moderate innovator classes are different in 2008 and in 2017. In 2008 Romania and Hungary were included in this class at 12 and 14 position respectively, whereas in 2017 their positions were lower (Romania dropped to 27 position, Hungary to 20) and thus they changed their

class into modest innovators. The improvement of innovation level in the context of sustainable development was observed in the case of Lithuania and Slovakia, which in 2008 were listed in the class of modest innovators at 20 and 21 positions, whereas in 2017 they improved respectively to 12 and 16 place, and therefore moved to the class of moderate innovators. In 2008 class 3 of modest innovators covered 10 and in 2017 11 countries, including only Greece and Portugal from among the so-called EU15 countries. In 2018 a single-element class of 4 non-innovators was distinguished, which included Latvia characterized by just slight development of innovation.

5. Conclusions

The following conclusions result from the conducted studies and analyses:

1. The EU countries are characterised by a significant diversification in terms of indicators describing innovation in the context of sustainable development which, however, shows a decreasing trend over time (the exception was the share of net revenues from the sale of innovative products in net revenues from total sales). The EU countries featured the greatest dispersion regarding the number of inventions filed by residents in the European Patent Office per 1 million population, and the smallest in terms of human resources for science and technology.

2. In 2008 4 classes and in 2017 3 classes of the EU countries were distinguished regarding the level of innovation in the context of sustainable development. In the years 2008 and 2017 the composition of the innovation leaders' class did not change and included Finland, Sweden, Denmark, Germany and Austria. The most numerous class of moderate innovators covered, in 2008, the other EU15 countries excluding Greece and Portugal, whereas in 2008 Romania and Hungary, and in 2017 Lithuania and Slovakia. The class of modest innovators in both analysed years included, apart from Greece and Portugal, 8 other countries of the new EU accession. In 2008, a one-element class of non-innovators was identified, which included Latvia presenting a diagnosed insignificant level of innovation development (the value of development measure was 0.092).

3. In both analysed periods the highest innovation level was diagnosed in Finland, while the lowest in 2008 in Latvia, and in 2017 in Bulgaria and then Romania.

The continuous monitoring of innovation indicators and the diagnosis of innovation development level in the context of sustainable development is of key importance for designing the development strategy and objectives of the European Union economic policy, as well as for the individual Member States. Public statistics faces the challenge of improving the currently used and identifying new indicators aimed at diagnosing the capacity of economies in creating and implementing innovations which have positive environmental and social impacts, as well as increasing the availability of data, the scope and quality of indicators used to measure and monitor progress in terms of innovation.

References:

Białoń, L. 2012. Ecological aspects of innovation activity. IN: *Economics and innovation management in the conditions of sustainable development*. Bialystok: University of Bialystok Press, 197.

Borys, T. 2011. Sustainable Development – How to Recognize Integrated Order. *Problems of Sustainable Development.* Vol. 6, n. 2, 75-81.

Central Statistical Office. 2018. [Online]. *Sustainable development indicators*. Retrieved from: http://wskaznikizrp.stat.gov.pl/index.jsf

Echeverria, J. 2008. The Oslo manual and the social innovation. *Arbor-Ciencia Pensamiento y Cultura*. Vol. 184, n. 732, 609-618.

Hellwig, Z. 1968. The application of taxonomic method for typological division of countries regarding their development level as well as the resources and structure of qualified personnel. *Statistical Review.* Vol. 4, 307-327.

Madej, Z. 1970. *Science and economic development*. Warsaw: PWE Publishers.

Michalski, R., Sawicki, J., Błaszczuk, D., Prandecki, K. 2015. *Towards sustainable development*. Warsaw: Vistula University, 113.

Niedzielski, P. 2011. Innovativeness. IN: *Innovations and technology transfer. The Dictionary of Terms*. Warsaw: Polish Agency for Enterprise Development, 119.

OECD/European Communities. 2005. *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*. 3rd Edition, 18-46.

.

Sobczak, E., Głuszczuk, D. 2016. Diversification of enterprise innovation activity level vs. gross domestic product level per capita in Polish regions. IN: *The 10th International Days of Statistics and Economics Online Conference Proceedings September 8–10.* Prague: Libuše Macáková MELANDRIUM, 1676.

Walesiak, M. 2006. *Generalised distance measure in statistical multivariate analysis*. Wrocław: Wrocław University of Economics Publishing House