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A Summary Assessment of Innovativeness of The New Member States of The European Union

Abstract

This paper attempts to assess the level of innovativeness of the economies of the 'new' EU member states[1] in the years 2008–2015, with particular attention paid to the position of the Polish economy. This assessment was carried out on the basis of a summary index constructed with the use of statistical methods of linear ordering. The paper also presents conclusions from the analysis of the evolution of selected factors characterizing the innovativeness of the new EU member states. In the conducted analysis, statistical data from Eurostat were used to describe the innovativeness of economies with respect to two areas: (a) science and technology; and (b) education and training.

The developed ranking of innovativeness of the new EU Member States, built on the basis of a summary index, makes it possible to state that the countries with the highest level of innovativeness among 13 analyzed countries were Slovenia, the Czech Republic and Malta. Poland's above-average value of the summary index for these countries occupied sixth position in the ranking, which indicates a relatively low level of innovativeness of the Polish economy.

Keywords: *innovation, innovativeness, summary index, multidimensional comparative analysis*

JEL: *O31, O33, E65*

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[1] Those countries which acceded to the EU in 2004 and later.

1. Introduction

Many modern world phenomena indicate that in order to understand the economic and social trends occurring in the global economy today it should be assumed that economic growth is increasingly dependent on knowledge and innovation. Natural resources and fixed capital determine the wealth of nations to a lesser extent than during the domination of the industrial economy (Pawłowski 2004, pp. 18–19). Research and development (R&D), innovative activities and human capital are becoming the main determinants of growth. The process of transition towards a knowledge-based economy is manifested in the increased competitive advantage of countries and regions specializing in the production of high-tech products. Innovativeness is therefore considered to be one of the most important factors determining modern countries' economic growth rate and their level of economic welfare (Okoń-Horodyńska 2004, p. 11–12).

The aim of this paper is to attempt to assess the level of innovativeness of the economies of the new EU member states[2] in the years 2008–2015, with particular emphasis put on the position of the Polish economy. This assessment was carried out using a summary index constructed on the basis of statistical methods of linear ordering. The assessment of the level of innovativeness of the economies is preceded by an analysis of some basic factors characterizing the innovativeness of the new EU member states. In this elaboration statistical data from *Eurostat* were used, describing innovativeness of the economies with respect to two areas: (a) science and technology; and (b) education and training.

2. The level and dynamics of selected indicators of innovativeness of the new EU member states

This part of the work focuses on static and dynamic analyses of selected indicators of innovativeness of the new EU member states. The indicators considered separately using a static approach constitute a valuable source of information about individual areas of innovativeness. The dynamic approach makes it possible to assess the relative direction of changes and enables comparisons between the countries. The beginning of the analyzed period is the year 2008 and the analyzed period ends the years 2013, 2014 or 2015, depending on the availability of data. The potential indicators of innovativeness were assigned to six groups, as presented in Table 1 below.

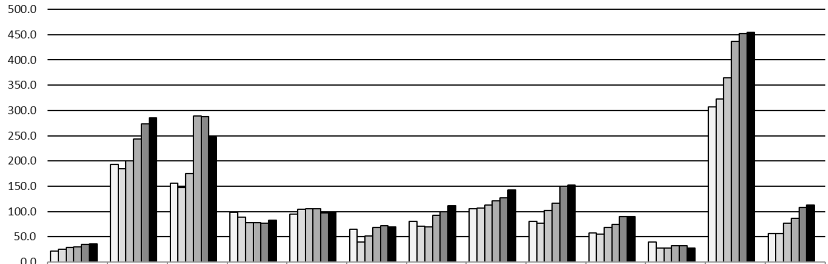
[2] See footnote 1 above.

Table 1. A set of potential diagnostic indicators of innovativeness of the new EU member states

Symbol	Indicator of innovativeness
Expenditures on R&D	
X1	Total expenditures on R&D in euro per inhabitant
X2	Expenditures on R&D in the business sector in euro per inhabitant
X3	Expenditures on R&D in the government sector in euro per inhabitant
X4	Expenditures on R&D in the higher education sector in euro per inhabitant
X5	Expenditures on R&D in the business sector as % of total expenditures
X6	Expenditures on R&D in the government sector as % of total expenditures
X7	Expenditures on R&D in the higher education sector as % of total expenditures
R&D personnel	
X8	R&D personnel and researchers as % of labor force
X9	Reaserchers as % of labor force
High technology	
X10	Trade in high technology in million euro per inhabitant
X11	Export of high technology as % of total export
X12	Employment in the industry of high and mid-high technology and in knowledge-intensive services as % of total employment
Patents	
X13	Patent applications to the EPO in the area of high technology per million inhabitants
X14	Patent applications to the EPO per million inhabitants
Education	
X15	Participation of people aged 18–64 in education and training
Trademarks	
X16	Number of Community trademark applications
X18	Publication of Community trademarks as % of all Community trademark applications
X19	Registration of Community trademarks as % of all Community trademark applications
X20	Community design applications per million inhabitants

Source: own elaboration.

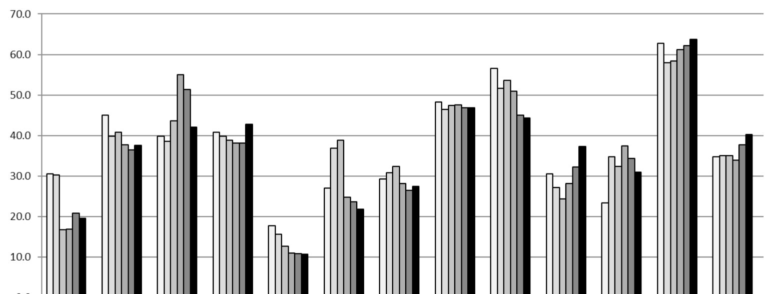
The analysis of the selected indicators presented in Table 1 leads to several conclusions. As shown in Figure 1, the highest levels of expenditures on R&D per capita over the period 2008–2013 were recorded in Slovenia (307 euro in 2008 and more than 454 euro in 2013), the Czech Republic (more than 193 euro in 2008 and 285 euro in 2013) and Estonia (155 euro in 2008 and 247 euro in 2013). Poland, like Croatia and Cyprus, recorded a relatively low level of expenditures on R&D (just over 90 euro per capita in 2013). In most countries, an average annual growth of the analyzed variable was observed in the analyzed period. The highest average annual growth rate was recorded in Slovakia (14%), Malta (14%) and Bulgaria (10%). Only Croatia and Romania showed an average annual decline of this indicator. In the case of Poland the level of expenditures on R&D per capita increased at an average yearly rate of 9%.



	Bulgaria	Czech Republic	Estonia	Croatia	Cyprus	Latvia	Lithuania	Hungary	Malta	Poland	Romania	Slovenia	Slovakia
2008	22.2	193.3	155.4	98.7	94.5	64.6	80.2	105.4	80.1	57.6	39.2	306.9	56.7
2009	24.7	184.6	147.8	88.3	104.1	39.2	70.2	106.4	77.3	55.0	27.2	323.2	56.3
2010	29.0	200.3	174.6	77.9	105.2	51.2	69.9	112.4	101.9	68.6	28.2	364.4	77.2
2011	29.8	243.3	289.1	78.4	105.8	67.8	92.6	120.6	116.2	74.5	32.5	436.2	86.9
2012	34.6	273.9	287.3	77.2	96.7	71.7	99.3	126.6	149.4	90.1	32.1	451.6	108.3
2013	36.3	285.0	247.0	83.3	99.4	69.1	111.9	142.8	152.7	90.3	27.9	454.1	112.9
average annual changes	110.3%	108.1%	109.7%	96.7%	101.0%	101.4%	106.9%	106.3%	113.8%	109.4%	93.4%	108.2%	114.8%

Figure 1. The level and dynamics of expenditures on R&D per capita in the new EU member states in the years 2008–2013

Source: own elaboration based on Eurostat data.



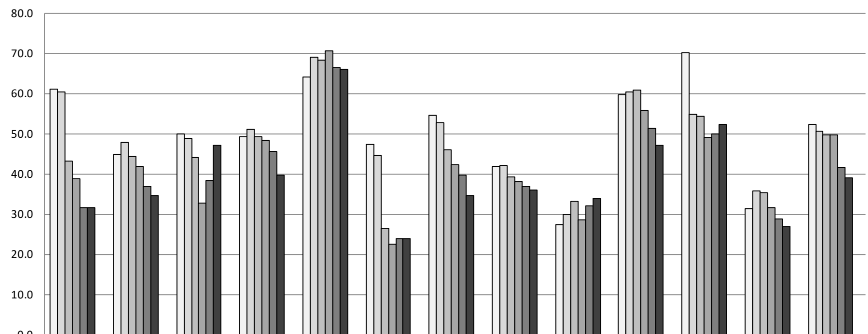
	Bulgaria	Czech Republic	Estonia	Croatia	Cyprus	Latvia	Lithuania	Hungary	Malta	Poland	Romania	Slovenia	Slovakia
2008	30.6	45.0	39.8	40.8	17.8	27.0	29.3	48.3	56.5	30.5	23.3	62.8	34.7
2009	30.2	39.8	38.5	39.8	15.7	36.9	30.8	46.4	51.6	27.1	34.8	58.0	35.1
2010	16.7	40.8	43.6	38.8	12.7	38.8	32.4	47.4	53.6	24.4	32.3	58.4	35.1
2011	16.9	37.7	55.0	38.2	11.0	24.8	28.2	47.5	51.0	28.1	37.4	61.2	33.9
2012	20.8	36.4	51.3	38.2	10.9	23.7	26.5	46.9	45.0	32.2	34.4	62.2	37.7
2013	19.5	37.6	42.1	42.8	10.7	21.8	27.5	46.8	44.3	37.3	31.0	63.8	40.2
average annual changes	91.4%	96.5%	101.1%	101.0%	90.3%	95.8%	98.7%	99.4%	95.3%	104.1%	105.9%	100.3%	103.0%

Figure 2. The level and dynamics of the share of expenditures on R&D in the business sector in the total expenditures on R&D in the new EU member states in 2008–2013

Source: own elaboration based on Eurostat data.

Based on the data showing the share of expenditures on R&D in the business sector in the total expenditures on R&D (Figure 2 below) it can be seen that in 2008–2013 the highest levels of this variable were recorded in Slovenia (approx. 63% in 2008 and 2013) and Hungary (over 48% in 2008 and almost 47% in 2013). The share of these expenditures observed in 2013 in Malta, Croatia, Estonia and Slovakia was just over 40%. In Poland this share amounted to 37%, just as in the Czech Republic. The relatively lowest levels of this analyzed variable were observed in Lithuania (29% in 2008 and 27.5% in 2013), Latvia (27% in 2008 and 21.8% in 2013) and Bulgaria (30.6% in 2008 and 19.5% in 2013). The countries which recorded an average annual increase in the share of expenditures on R&D in the business sector in relation to the overall level of these expenditures were Romania (6%), Poland (4%), Slovakia (almost 3%), Estonia (1%), Croatia (1%) and Slovenia (0.3%). In the other countries a decrease in this variable was recorded.

As regards the share of expenditures on R&D in the government sector in the total expenditures on R&D[3] (Figure 3 below) it should be noted that the highest levels of the variable in 20082013 were recorded in Romania (over 70% in 2008 and more than 52% in 2013), and in Poland and Estonia (47.2% in 2013 in both countries). The share of these expenditures in 2013 in Croatia, Slovakia, Hungary, Lithuania and Malta was slightly less than 40%. The lowest values of the analyzed variable were recorded in 2013 in Latvia (24%) and Slovenia (26.9%). Only two countries – Malta and Cyprus – showed an average annual increase in the share of expenditures in the government sector in relation to the total expenditures on R&D in the analyzed period.

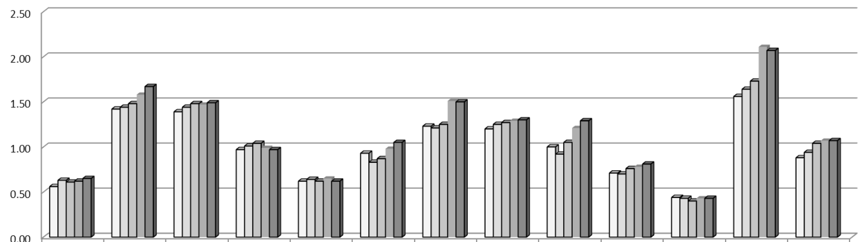


	Bulgaria	Czech Republic	Estonia	Croatia	Cyprus	Latvia	Lithuania	Hungary	Malta	Poland	Romania	Slovenia	Slovakia
2008	61.2	44.8	50.0	49.3	64.1	47.3	54.6	41.8	27.4	59.8	70.1	31.3	52.3
2009	60.5	47.8	48.8	51.2	69.0	44.7	52.7	42.0	30.0	60.4	54.9	35.7	50.6
2010	43.2	44.4	44.1	49.2	68.3	26.4	46.0	39.3	33.3	60.9	54.4	35.3	49.6
2011	38.8	41.7	32.8	48.2	70.6	22.5	42.2	38.1	28.5	55.8	49.1	31.5	49.8
2012	31.5	36.8	38.3	45.5	66.4	23.9	39.7	36.9	32.1	51.3	49.9	28.7	41.6
2013	31.6	34.7	47.2	39.7	66.0	23.9	34.5	35.9	33.9	47.2	52.3	26.9	38.9
average annual changes	87.6%	95.0%	98.9%	95.8%	100.6%	87.2%	91.2%	97.0%	104.3%	95.4%	94.3%	97.0%	94.3%

Figure 3. The level and dynamics of the share of expenditures on R&D in the government sector in the total expenditures on R&D in the new EU member states in 2008–2013

Source: own elaboration based on Eurostat data.

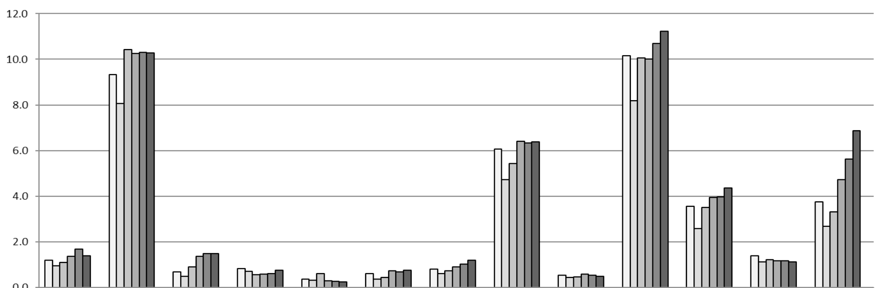
[3] Expenditures on R&D in the government sector are considered to be a specific type of variable affecting the level of innovativeness of the economy. As they are determined by political decisions, rather than, as in the case of private sector investments, by market mechanisms, they have a smaller impact on raising the level of innovativeness than expenditures on R&D in the business sector.



	Bulgaria	Czech Republic	Estonia	Croatia	Cyprus	Latvia	Lithuania	Hungary	Malta	Poland	Romania	Slovenia	Slovakia
2008	0.56	1.42	1.39	0.97	0.62	0.93	1.23	1.20	1.00	0.71	0.44	1.56	0.88
2009	0.63	1.44	1.44	1.01	0.64	0.83	1.21	1.25	0.92	0.70	0.43	1.64	0.94
2010	0.61	1.48	1.48	1.04	0.62	0.87	1.25	1.27	1.05	0.76	0.40	1.73	1.04
2011	0.62	1.58	1.47	0.99	0.65	0.98	1.51	1.29	1.21	0.78	0.43	2.11	1.07
2012	0.65	1.67	1.49	0.97	0.62	1.05	1.50	1.30	1.29	0.81	0.43	2.07	1.07
average annual changes	103.8%	104.1%	101.8%	100.0%	100.0%	103.1%	105.1%	102.0%	106.6%	103.3%	99.4%	107.3%	105.0%

Figure 4. The level and dynamics of the share of employment in R&D and researchers in the total labor force in the new EU member states in 2008–2012

Source: own elaboration based on Eurostat data.



	Bulgaria	Czech Republic	Estonia	Croatia	Cyprus	Latvia	Lithuania	Hungary	Malta	Poland	Romania	Slovenia	Slovakia
2008	1.2	9.3	0.7	0.8	0.4	0.6	0.8	6.1	0.5	10.2	3.6	1.4	3.7
2009	0.9	8.1	0.5	0.7	0.3	0.4	0.6	4.7	0.4	8.2	2.6	1.1	2.7
2010	1.1	10.4	0.9	0.6	0.6	0.4	0.7	5.4	0.5	10.1	3.5	1.2	3.3
2011	1.4	10.3	1.4	0.6	0.3	0.7	0.9	6.4	0.6	10.0	4.0	1.2	4.7
2012	1.7	10.3	1.5	0.6	0.3	0.7	1.0	6.3	0.5	10.7	4.0	1.2	5.6
2013	1.4	10.3	1.5	0.8	0.2	0.8	1.2	6.4	0.5	11.2	4.4	1.1	6.9
average annual changes	103.6%	103.8%	114.8%	103.0%	94.5%	107.6%	108.6%	101.9%	91.5%	103.3%	103.7%	98.0%	110.7%

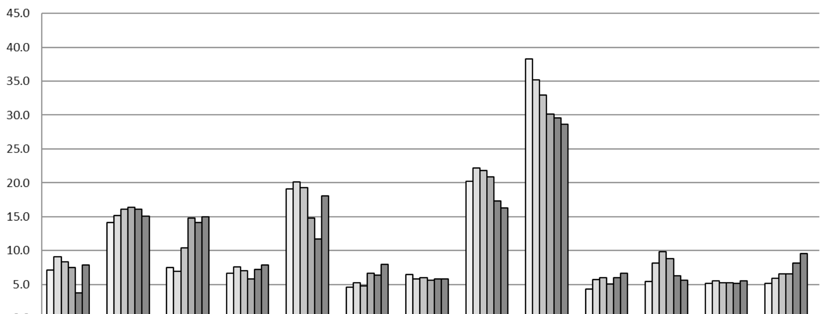
Figure 5. The level and dynamics of the share of exports of high technology products in the total exports of the new EU member states in 2008–2013

Source: own elaboration based on Eurostat data.

Another analyzed variable is the share of people employed in R&D and researchers in the total labor force (Figure 4). In the period 2008–2012 the highest levels of this variable (above 1%) were observed in Slovenia (1.56% in 2008 and 2.07% in 2012), the Czech Republic (1.42% in 2008 and 1.67% in 2012), Lithuania and Estonia (1.5% each in 2012), Hungary and Malta (1.3% each in 2012) and Latvia (1.05%). In Poland, this share amounted to 0.71% in 2008 and 0.81% in 2012 and in 2012 it was only higher than the values of this variable for Bulgaria, Cyprus and Romania. In all surveyed countries, average increases in the analyzed variable were observed, with the exception of Cyprus and Croatia (the values of which did not change), and Romania, where the value of the indicator decreased.

Based on the analysis of data describing the share of export of high technology products in total exports (Figure 5) it can be stated that the countries with the highest levels of this variable in 2008–2013 were Malta (38% in 2008 and 29% in 2013), Estonia (over 15% in 2013), the Czech Republic (14.1% in 2008 and 15.1% in 2013) and Hungary (20.2% in 2008 and 16.3% in 2013). The value of this indicator for Poland was 4.3% in 2008 and 6.7% in 2013. Most of the surveyed countries showed an average annual increase in the share of exports of high technology products in the total exports in the analyzed period, with the largest increase recorded in Estonia and Slovakia (13% each), Latvia (12%) and Poland (10%). Bulgaria, Croatia, Cyprus, Lithuania, Hungary and Malta recorded a decrease in the analyzed variable.

As regards the share of employment in industry of high and mid-high technologies and in knowledge-intensive services in total employment (Figure 6), it can be seen that the countries with the highest levels of this variable in 2008–2013 were the Czech Republic (10.2% in 2008 and 10.8% in 2013), Slovakia (10.2% in 2008 and 9.8% in 2013), Hungary (8.6% in 2008 and 8.5% in 2013) and Slovenia (9.1% in 2008 and 8.3% in 2013). In Poland, the employment in this area in the analyzed period was close to 5% of total employment. The countries with the lowest levels of this indicator (below 2%) were Cyprus and Latvia. Most countries reported an average annual decline of employment in this area in the analyzed period. Among the countries that showed a slight increase were the Czech Republic, Estonia and Cyprus.

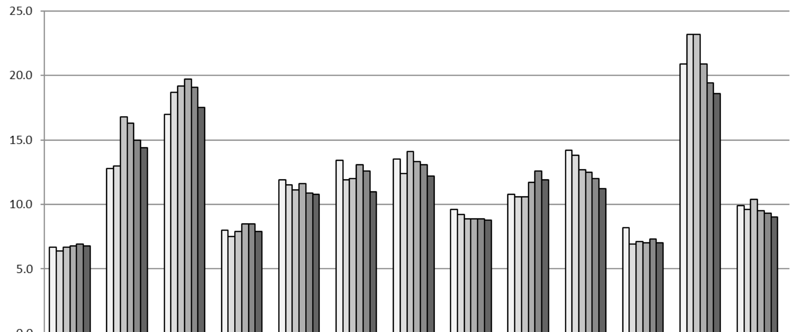


	Bulgaria	Czech Republic	Estonia	Croatia	Cyprus	Latvia	Lithuania	Hungary	Malta	Poland	Romania	Slovenia	Slovakia
2008	7.1	14.1	7.5	6.7	19.1	4.6	6.5	20.2	38.3	4.3	5.4	5.2	5.2
2009	9.1	15.2	6.9	7.6	20.1	5.3	5.8	22.2	35.2	5.7	8.2	5.5	5.9
2010	8.3	16.1	10.4	7.0	19.3	4.8	6.0	21.8	32.9	6.0	9.8	5.3	6.6
2011	7.5	16.4	14.8	5.8	14.8	6.7	5.6	20.9	30.1	5.1	8.8	5.3	6.6
2012	3.8	16.1	14.1	7.2	11.7	6.4	5.8	17.3	29.6	6.0	6.3	5.2	8.2
2013	7.9	15.1	15.0	7.9	18.1	8.0	5.8	16.3	28.6	6.7	5.6	5.5	9.6
average annual changes	90.5%	101.4%	113.8%	99.7%	88.0%	112.2%	99.7%	94.5%	95.4%	110.2%	102.9%	100.3%	113.0%

Figure 6. The level and dynamics of the share of employment in industry of high and mid-high technologies and knowledge-intensive services in total employment in the new EU member states in 2008–2013

Source: Own elaboration based on Eurostat data.

The data describing the participation of persons aged 18–64 years in education and training (Figure 7) show that the countries with the largest values of this variable in the period 2008–2014 were Slovenia (20.9% in 2008 and 18.6% in 2014), Estonia (17% in 2008 and 2014) and the Czech Republic (13% in 2008 and 14.4% in 2014). The participation in education and training of this group in Poland was 14.2% in 2008 and 11.2% in 2014, which was comparable to the level of this indicator for Lithuania, Latvia, Malta and Cyprus. In most countries, an average annual decline in this variable was recorded in the analyzed period, although a few countries – the Czech Republic, Estonia, Malta, Estonia and Bulgaria – reported a slight annual average increase.

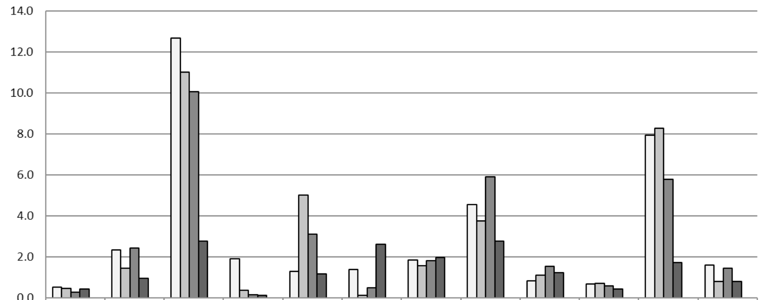


	Bulgaria	Czech Republic	Estonia	Croatia	Cyprus	Latvia	Lithuania	Hungary	Malta	Poland	Romania	Slovenia	Slovakia
2008	6.7	12.8	17.0	8.0	11.9	13.4	13.5	9.6	10.8	14.2	8.2	20.9	9.9
2010	6.4	13.0	18.7	7.5	11.5	11.9	12.4	9.2	10.6	13.8	6.9	23.2	9.6
2011	6.7	16.8	19.2	7.9	11.1	12.0	14.1	8.9	10.6	12.7	7.1	23.2	10.4
2012	6.8	16.3	19.7	8.5	11.6	13.1	13.3	8.9	11.7	12.5	7.0	20.9	9.5
2013	6.9	15.0	19.1	8.5	10.9	12.6	13.1	8.9	12.6	12.0	7.3	19.4	9.3
2014	6.8	14.4	17.5	7.9	10.8	11.0	12.2	8.8	11.9	11.2	7.0	18.6	9.0
average annual changes	100.2%	102.0%	100.5%	99.8%	98.4%	96.8%	98.3%	98.6%	101.6%	96.1%	97.4%	98.1%	98.4%

Figure 7. The level and dynamics of participation of persons aged 18–64 in education and training in the new EU member states in 2008–2014

Source: Own elaboration based on Eurostat data.

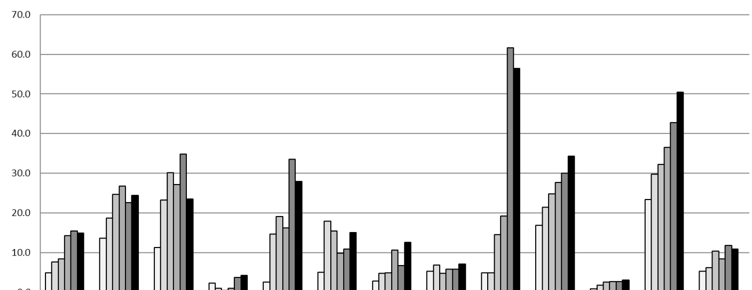
Another analyzed variable was patent applications to the European Patent Office (EPO) in the area of high technologies, per million inhabitants (Figure 8). The countries with relatively high values of this variable in the period 2008–2012 were Hungary (4.6 in 2008 and 2.8 in 2012), Estonia (12.7 in 2008. and 2.8 in 2012), Latvia (1.4 in 2008 and 2.6 in 2012), Lithuania (1.8 in 2008 and 2.0 in 2012) and Slovenia (7.9 in 2008 and 1.7 in 2012). The number of patent applications to the EPO in the field of high technology in Poland was 1.2 per million inhabitants in 2012, which was comparable with the number of applications in Cyprus. For other countries, the analyzed indicator in 2012 was below 1.0. Most of the surveyed countries recorded an average annual decline in the number of patent applications in this period. Only three countries showed an increase in the analyzed variable: Latvia (17.5%), Poland (10.3%) and Lithuania (1.7%).



	Bulgaria	Czech Republic	Estonia	Croatia	Cyprus	Latvia	Lithuania	Hungary	Malta	Poland	Romania	Slovenia
2008	0.5	2.3	12.7	1.9	1.3	1.4	1.8	4.6	0.8	0.7	7.9	1.6
2009	0.4	1.4	11.0	0.3	5.0	0.1	1.6	3.7	1.1	0.7	8.3	0.8
2011	0.3	2.4	10.1	0.2	3.1	0.5	1.8	5.9	1.5	0.6	5.8	1.4
2012	0.4	0.9	2.8	0.1	1.2	2.6	2.0	2.8	1.2	0.4	1.7	0.8
average annual changes	96.0%	79.6%	68.4%	49.8%	97.4%	117.5%	101.7%	88.3%	110.3%	89.0%	68.1%	84.1%

Figure 8. The level and dynamics of the number of patent applications to the European Patent Office (EPO) in the field of high technologies, per million inhabitants in the new EU member states in 2008–2012

Source: Own elaboration based on Eurostat data.



	Bulgaria	Czech Republic	Estonia	Croatia	Cyprus	Latvia	Lithuania	Hungary	Malta	Poland	Romania	Slovenia	Slovakia
2008	4.9	13.5	11.2	2.3	2.6	5.0	2.8	5.3	4.9	16.8	0.9	23.4	5.2
2010	7.6	18.7	23.3	0.9	14.7	17.9	4.8	6.9	4.8	21.4	1.8	29.8	6.1
2011	8.4	24.7	30.1	0.5	19.1	15.4	4.9	4.7	14.5	24.8	2.5	32.2	10.4
2012	14.3	26.8	27.2	0.9	16.2	9.8	10.6	5.7	19.2	27.6	2.7	36.5	8.3
2013	15.4	22.5	34.8	3.8	33.5	10.9	6.7	5.9	61.7	30.0	2.7	42.7	11.8
2014	14.9	24.5	23.6	4.2	28.0	15.0	12.6	7.1	56.4	34.3	3.0	50.5	10.9
average annual changes	120.3%	110.4%	113.2%	110.5%	148.8%	120.0%	128.4%	105.0%	150.3%	112.6%	123.0%	113.7%	113.1%

Figure 9. The level and dynamics of the number of Community design applications per million inhabitants in the new EU member states in 2008–2014

Source: own calculations based on Eurostat data.

The analysis of the number of Community design applications per million inhabitants (Figure 9) shows that in the period 2008–2014 the highest level of the variable was recorded in Slovenia (23.4 in 2008 and 50.5 in 2014) and Malta (56.4 in 2014), which countries also showed the highest average annual growth of the number of Community designs in this group of countries, amounting to 50%. Among the countries which also recorded a relatively high average annual increase in this variable were: Cyprus (49%), Lithuania (28%), Romania (23%), Latvia and Bulgaria (20% each). In Poland, which reported more than 34 Community design applications per million inhabitants in 2014, the average annual growth rate of this variable was 12.6%.

Analysis of variables describing various areas of innovativeness of the economies of the new EU member states leads, when considered individually, to the conclusion that the Polish economy is characterized by a relatively low level of innovativeness. This applies above all to the innovativeness associated with „science and technology" (expenditures on R&D per capita, expenditures on R&D in the business sector, employment in R&D, export of high-technology, patent applications to the EPO in the area of high technology).

3. Assessment of the level of innovativeness of the new Member States using the summary index

The use of tools of multidimensional comparative analysis (MCA) makes in possible, thanks to constructing a summary measure, to compare the overall level of innovativeness between the countries and to rank them in terms of their development in this particular area. The starting point for each method of linear ordering is the proper selection of diagnostic variables, i.e. variables that significantly characterize the complex and multidimensional investigated phenomenon. The initial set of potential features (indicators), determined on the basis of substantive and formal premises, has been presented in Table 1, where the total number of input variables (20) are divided into six categories.

All potential features describing innovativeness are treated as stimulants, i.e. features for which higher values indicate a higher level of innovativeness of the economy. As the time series ends in 2014 or 2015 in the case of a few variables, the data from 2013 were selected in order to build a summary index.

Because of the missing data for some countries, in the first step of the preliminary analysis of the data the variables numbered 4, 7 and 18 were eliminated from the set of potential diagnostic indicators adopted to assess the level of innovativeness.

In the next step, the usefulness of other indicators for analysis was assessed, based on the measures of descriptive statistics. At this stage the set of diagnostic indicators was selected from a set of acceptable indicators, on the basis of substantive and formal premises. This is an important step because too many diagnostic variables, which may be unimportant or excessively correlated with each other, can impede obtaining a proper – i.e. best in terms of quality – result of linear ordering of objects (in this case the new EU member states).

When selecting the diagnostic features the following informative criteria should be used (Ostasiewicz 1999, p. 110): universality – the features should be widely recognized as important and significant for the analysis; variability – the features should not be similar to each other in terms of information about the analyzed objects, and should have a high ability to differentiate objects (high variability); significance – indicators with regard to which it is difficult for the analyzed objects to reach high (significant) values; and correlation – selected indicators should be weakly correlated with one another, while strongly correlated with indicators excluded from the analysis by reduction.

To assess the variability of potential diagnostic indicators the relative measure of dispersion, i.e. classical coefficient of variation (v_j) may be used. From the set of potential diagnostic indicators those indicators for which $|v_j| < 0.1$ were eliminated. The indicator X19 (registration of Community trademarks as % of all Community trademark applications), which was characterized by a very low variation, was eliminated from the set of 17 potential diagnostic indicators.

Another measure of variation is the coefficient of relative amplitude of fluctuations $A(X_j)$ of a particular indicator, which informs how many times the highest value of the indicator for the first object in the ranking is higher than the lowest value of this indicator for the last object in the ranking (for destimulants the interpretation is reversed) (Kukuła 2000, pp. 47–52):

$$A\left(X_j\right) = \frac{\max\limits_i x_{ij}}{\min\limits_i x_{ij}}, \ \left(i = 1,..., n; j = 1,..., m\right), \tag{1}$$

where $\min\limits_i x_{ij} \neq 0$. A sufficient amplitude of fluctuations was set at the level: $A(X_j) \geq 1{,}2$

All the features adopted in this work were characterized by a sufficient amplitude of fluctuations.

In the last step of the preliminary data analysis the correlation of potential diagnostic indicators was assessed. For this purpose, from the set of various methods of reduction and selection of diagnostic variables and taking into account their informative potential, the parametric Hellwig method was applied.[4] This method is based on a matrix of Pearson linear correlation coefficients and it excludes features which are strongly correlated with other features, mostly at levels higher than 0.9 (the level adopted in this work). In such a case, these features repeat information already contained in other features and their elimination does not affect the calculation results. These are called satellite variables. In this work, such variables appeared to be: X2, X3, X9, X14 and X17. The target data set should consist only

[4] This method is described in detail in, *inter alia*: T. Panek, Statystyczne metody wielowymiarowej analizy porównawczej, SGH, Warszawa 2009, pp. 20–21

of the so-called central features (X1, X5, X8, X10, X16, X20) and isolated features (X6, X11, X12, X13, X15).

The analysis of correlation led to the sequential removal of indicators: 2, 3, 9, 14, 17 from further analysis. Finally, the set of 11 diagnostic indicators listed in Table 2 was used to build the rankings of innovativeness of the countries chosen for study.

Table 2. Diagnostic indicators of the level of innovativeness of the new EU member states

No.	Symbol	Preferences	INDICATORS
1	X1	S	Expenditures on R & D in euro per inhabitant
2	X5	S	Expenditures on R&D in the business sector as % of total expenditures
3	X6	S	Expenditures on R&D in the government sector as % of total expenditures
4	X8	S	R&D personnel and researchers as % of labor force
5	X10	S	Trade in high technology per inhabitant, in million euro
6	X11	S	Export of high technology as a % of total exports
7	X12	S	Employment in industries of high and mid-high technologies and knowledge-intensive services as % of total employment
8	X13	S	Patent applications to the EPO in the area of high technologies, per million inhabitants
9	X15	S	Participation of people aged 18–64 in education and training
10	X16	S	Number of Community trademark applications
11	X20	S	Community design applications, per million inhabitants

S – stimulus

Source: own elaboration.

Prior to the linear ordering of objects, which requires the selection of data aggregation formula, the variables should be normalized and weighted. In this work equal weight was assigned to all the diagnostic features, thus giving them the same importance.

The basic requirement in the normalization procedures is that the transformation retains correlation between the features and key indicators regarding the shape of their distributions (skewness, kurtosis). Such properties are observed in case of the transformation of a linear variable $X_j = (x_{1j}, x_{2j}, \ldots, x_{nj})^T$ into the variable $Z_j = (z_{1j}, z_{2j}, \ldots, z_{nj})^T$ in the form (Zeliaś 2000, p. 792):

$$z_{ij} = \frac{x_{ij} - a_j}{b_j}, \ (j = 1, \ldots, m). \quad (2)$$

$$z_{ij} = \frac{a_j - x_{ij}}{b_j}, \ (j = 1, \ldots, m), \quad (3)$$

for stimulants (2) and destimulants (3) respectively; whereby, if a_j is a measure of the location of the feature, for example. the arithmetic mean $a_j = \bar{x}_j$, and b_j is a measure of its variation, e.g. standard deviation ($b_j = s_j$) then this is the standarization transformation; if b_j is a measure of variation – the range $b_j = \max_i x_{ij} - \min_i x_{ij}$, then this is the unitarization transformation.

Many normalization transformations can be found in the literature as it is acceptable to substitute the parameters a_j and b_j also with other characteristics of the analyzed variables,[5] respectively: the minimum, maximum, median; and the median absolute deviation, the sum of x_{ij} or the sum of the squares of x_{ij}. An analysis of theoretical properties of different normalization methods (Kukuła 2000, pp. 77–100) allows for assessment of their applicability, selection and use for the purpose of linear ordering of objects of transformations showing the best properties.

It appears that only the zeroed unitarization method, with parameters, respectively, $a_j = \max_i x_{ij}$ and $b_j = \max_i x_{ij} - \min_i x_{ij}$ for stimulants, and $a_j = \max_i x_{ij}$ and $b_j = \max_i x_{ij} - \min_i x_{ij}$ for destimulants, which gives the normalized values of the diagnostic indicators from the range $\langle 0;1 \rangle$, meets all the theoretical postulates of the normalization formula and ensures a universal normalization of all the features. Further methods include: the classic formula of standardization with parameters $a_j = \bar{x}_j$ and $b_j = s_j$ and ratio transformation with parameters $a_j = 0$ and $b_j = \sum_{i=1}^{n} x_j$.

In this work, the variables were adjusted for comparability using the classical standardization (variant I) and zeroed unitarization (variant II).

An appropriate step at the stage of the linear ordering of objects is the selection of the formula of aggregation of diagnostic variables. The most frequently used formulas include two types of methods of linear ordering (Grabiński, Wydymus, Zeliaś 1989, pp. 31–32): based on models; not based on models involving the construction of the synthetic measure; as well as a group of methods of orthogonal projection of points onto a straight line. In this work a method not based on models was chosen.

The calculations included aggregation of the diagnostic indicators by summing their normalized values (Gatnar, Walesiak 2004, p. 355). This gives exactly

[5] With respect to the standardization procedures it should be noted that Grabinski et al. 1989, pp. 27–28 indicate three transformations most commonly used in the practice; and Domanski et al. 1998, pp. 49–48 present five standardization transformations and 10 ratio transformations; Kukuła 2000, pp. 106–110 applies a different division of normalization methods and discusses 10 normalization transformations; Zeliaś 2002, pp. 792–794 presents two methods of standardization, four methods of unitarisation, and six ways of ratio transformation; Walesiak 2006, pp. 16–22 analyzes a total of 11 transformations; and Młodak 2006, pp. 39–42, presents four methods of standardization, seven methods of unitarization and eight methods of ratio transformation, among which are also the author's proposals that use order statistics.

the same result of linear ordering of objects as aggregation according to the arithmetic average of the normalized values of diagnostic indicators.

The results of linear ordering of the new European Union member states for variant I (classical standardization of diagnostic indicators) and variant II (zeroed unitarization of diagnostic indicators) are presented in Table 3.

Table 3. Results of linear ordering of the new EU member states

No.	Country	Summary index M	Position	Summary index M	Position
		Variant I – classical standardization of diagnostic indicators		Variant II – zeroed unitarization of diagnostic indicators	
1	Bulgaria	–7.150	11	2.100	12
2	Croatia	–6.369	10	2.261	10
3	Czech Republic	7.884	2	6.524	2
4	Cyprus	–7.438	12	2.157	11
5	Estonia	4.789	4	5.640	4
6	Lithuania	–2.738	8	3.412	9
7	Latvia	–2.741	9	3.448	8
8	Malta	5.401	3	5.679	3
9	Poland	3.025	6	5.098	6
10	Romania	–8.546	13	1.784	13
11	Slovakia	–0.370	7	4.145	7
12	Slovenia	10.496	1	7.092	1
13	Hungary	3.758	5	5.349	5

Source: own elaboration based on research results.

In comparing variant I and variant II of linear ordering of these countries it can be stated that the results are very similar. The only changes of places were between Lithuania and Latvia and between Cyprus and Bulgaria in these rankings.

Based on the criterion of maximizing the directional variance of the summary measure,[6] which in this case required the transformation of the summary measure M to the outcome of the orthogonal projection of objects onto a straight line M^*, the results obtained in variant II of the analysis were considered to be a „better" ranking of innovation of the selected EU countries, as illustrated in Figure 11.

On the basis of the presented ranking of innovativeness of the new EU Member States, built with the use of a summary index of the innovativeness of the economy, it can be said that these countries differ in terms of its level. The conducted analysis shows that in 2013 the most innovative economy in the light of diagnostic indicators adopted for the analysis was Slovenia (7.092). The Czech Republic ranked second (6.524), with Malta (5.679) classified in the third place.

[6] This method is described in: M. Kolenda, Taksonomia numeryczna. Klasyfikacja, porządkowanie i analiza obiektów wielocechowych, Wydawnictwo Akademii Ekonomicznej we Wrocławiu, Wrocław 2006, pp. 137–140.

A similar level of innovativeness was observed in Estonia (5.640). Poland ranked only sixth, but it is worth noting that this is the last country in the ranking with the value of the index (5.098) above the average for the analyzed group of countries (4.207). As many as seven of the new EU member states, i.e. Slovakia, Latvia, Lithuania, Croatia, Cyprus, Bulgaria and Romania, were characterized by a level of innovativeness below the average for all analyzed countries. The last places in the ranking were taken by Bulgaria and Romania.

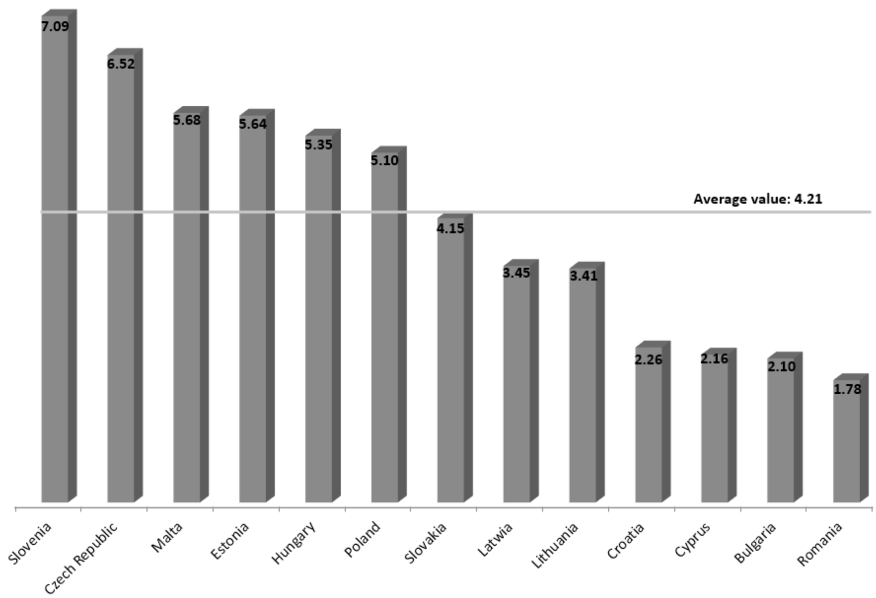


Figure 11. Ranking of innovativeness of the new EU member states in 2013

Source: Own elaboration based on research results.

When analysing the results of the ranking, it is worthwhile to observe the distribution of the maximum (favourable) and the minimum (unfavourable) values of diagnostic variables in different countries, that is, those that contributed to the success of the economy or those that caused their distant place in the ranking (Table 4). This facilitates the identification of the most significant features for the particular area. In this table the value 1 is assigned to the most favourable value of the feature, the value of 0 – the least favourable value of the feature.

The analysis of the data presented in Table 4 shows that Slovenia – the leader of the ranking – recorded the best, i.e. maximum, values in relation to four features: expenditures on R&D per capita; expenditures on R&D in the business sector; the share of R&D personnel and researchers in total employment; and participation of people aged 18–64 in education and training. For Slovenia only one feature was identified with having an unfavourable level, i.e. the share of export of high technology products in total export. Countries occupying the next places in the ranking (except Estonia) – Czech Republic, Malta and Hungary, showed one feature each with the maximum value and did not record any feature with an unsatisfactory level. In case of Poland two features reaching maximum level were observed, i.e. trade in high technology and the number of Community trademark applications. Countries remaining in the „bottom" of the ranking did not reach the maximum values in case of any feature (with the exception of Cyprus, with one positive feature) but had relatively many negative features, which contributed to their low position.

Table 4. Favorable (1) and unfavorable (0) levels of diagnostic variables in the new EU member states in 2013

Country	Number of diagnostic variable											∑1	∑0
	X1	X5	X6	X8	X10	X11	X12	X13	X15	X16	X20		
Slovenia	1	1		1		0			1			4	1
Czech Republic							1					1	0
Malta						1					1	2	0
Estonia												0	0
Hungary								1				1	0
Poland					1					1		2	0
Slovakia												0	0
Latvia			0							0		0	2
Lithuania												0	0
Croatia								0				0	1
Cyprus		0	1		0		0					1	3
Bulgaria									0			0	1
Romania	0			0							0	0	3

Source: own elaboration.

4. Conclusions

The results of this work clearly indicate that the level of innovativeness of the Polish economy is low. In the ranking of 13 new EU member states, built on the basis of a summary index of innovativeness, Poland occupies only the sixth place. It can therefore be concluded that the results of the innovation policy carried out so far within the process of Poland's integration with the European Union are unsatisfactory. Analysis of the reasons for this situation falls outside the scope of this article, but the main shortcomings of this policy should be mentioned. These include, *inter alia*: a low level of expenditures on research and development, including the expenditures of the private sector; the lack of permanent links between scientific and research institutions and enterprises; a low level of sophistication of patenting activity; a poorly developed market for venture capital; lack of an education system focused on developing creativity and collaboration skills. It is therefore necessary work towards reconstruction of the existing model for promoting the development of innovation in Poland. The success of this project depends on many different factors, related not only to the sphere of economic policy but also to the social and cultural conditions.

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Streszczenie

SYNTETYCZNA OCENA INNOWACYJNOŚCI NOWYCH KRAJÓW CZŁONKOWSKICH UNII EUROPEJSKIEJ

W artykule została podjęta próba oceny poziomu innowacyjności gospodarek nowych krajów członkowskich Unii Europejskiej w latach 2008–2015, ze szczególnym uwzględnieniem pozycji gospodarki polskiej. Oceny tej dokonano w oparciu o wskaźnik syntetyczny zbudowany na podstawie statystycznych metod porządkowania liniowego. W artykule przedstawiono również wnioski wynikające z analizy kształtowania się wybranych czynników charakteryzujących innowacyjność nowych krajów członkowskich Unii Europejskiej. Do badania wykorzystano dane statystyczne pochodzące z Eurostatu, opisujące innowacyjność gospodarek, ujęte w dwóch obszarach: (a) nauka i technika oraz (b) edukacja i szkolenia.

Na podstawie opracowanego rankingu innowacyjności nowych krajów członkowskich UE, zbudowanego w oparciu o wskaźnik syntetyczny, można skonstatować, że naj-

wyższym poziomem innowacyjności wśród 13 rozważanych krajów charakteryzowały się Słowenia, Czechy i Malta. Polska, z wartością wskaźnika syntetycznego powyżej średniej dla badanej grupy krajów, zajęła szóstą pozycję, co świadczy o relatywnie niskim poziomie innowacyjności jej gospodarki.

Słowa kluczowe*: innowacja, innowacyjność, wskaźnik syntetyczny, wielowymiarowa analiza komparatywna*