PUBLIC RESEARCH AND DEVELOPMENT IN EUROPEAN UNION COUNTRIES - EVALUATION BASED ON SELECTED INDICATORS

Martina Halásková, Pavel Bednář

Abstract: *Research, development and innovation hold a prominent position in national economies and the public sector. The aim of the paper is to evaluate the role of public research in EU countries with focus on selected indicators of research and development (R&D). The area in focus is total R&D expenditures and public R&D expenditures in years 2010 and 2015. The author also strives to analyze other R&D indicators in EU countries, pointing out the similarities and differences in the particular countries. The analysis concentrates on not only the selected indicators of public R&D, but also a comprehensive evaluation and role of public research in EU countries. EU countries are evaluated on the basis of indicators of public R&D by means of factor analysis, cluster analysis and box-plot, divided into four clusters depending on internal similarity in 2015. The most marked differences were observed in indicators of public research (R&D public expenditures as % of total R&D expenditures, researchers in public sector as % of total researchers, number of publications per 1000 researchers in the public sector, number of citable publications per 1000 researchers in the public sector) in the first cluster in comparison to the third cluster. In case of the indicator H-index (per 1000 researchers in the public sector) the most marked differences were observed in most countries of the second cluster in comparison to countries of the fourth cluster.*

Keywords: *Research and Development, Public R&D, R&D Public Expenditure, Indicators of R&D, EU Countries*

JEL Classification: *H54, H76, O32.*

Introduction

Science, research, development and innovations are one of the numerous sources of economic growth and social welfare. In the European dimension, the role of public R&D is accentuated mainly with respect to the goal of the Europe 2020 strategy. To implement the strategy Europe 2020 in the field of R&D, areas to focus on are better conditions for financing research, development and innovations, where financial capabilities of the EU countries are an important prerequisite. In R&D, member states should begin investing 3% of their GDP (1% public expenditures, 2% expenditures from the private sector) by no later than 2020 (OECD, 2015; EC, 2016b).

The aim of the paper is to evaluate public research and development (R&D) in EU countries with particular focus on selected indicators, applying theoretical and empirical approach. The paper concentrates on two financial indicators (total R&D expenditures and R&D public expenditures) in 2010 and 2015, which represent the basis of the Europe 2020 strategy in R&D. The author strives to evaluate other R&D indicators in EU countries, pointing out similarities and differences in the particular countries. The analysis concentrates on not only the selected indicators of public R&D, but also a comprehensive evaluation and role of public research on the basis of the

selected indicators in EU countries in 2015. Compared to other analyses which observe and analyze financial indicators and indicators of financial performance in EU countries (e.g. Albu, 2011; Szarowska, Žurkova, 2017; Tkač et al., 2017), the present evaluation also makes use of indicators of efficiency and quality of public research, which enable a more objective view on the role of public R&D in the given countries. With regard to the aim, the following research question (RQ1) is tested: Is the role of public R&D more prominent in countries with lower R&D intensity (total R&D expenditure as % of GDP), or vice versa?

1 Statement of a problem

Research in the public sector is mainly connected with basic research and is currently focusing on the acquisition of unique information in border areas, which contribute to both general growth of knowledge and the enhancement of innovation performance as well as the maintenance of sustainable development. Public research in EU countries, according to the OECD (2015), includes activities of the government sector and higher-education sector. The government sector is connected with public research institutions carrying out R&D in most cases as their major economic activity. The higher-education sector includes R&D workplaces, mainly faculties and other places of public and state-owned universities, teaching hospitals, private universities and other research institutions of post-secondary education. According to the EC (2016 b), however, the public sector itself is quite diverse. Public research is, broadly speaking, performed in either Higher Education Institutions (HEIs) or Public Research-performing Organisations (PROs) and both of these sectors contain a very diverse range of institutions of different sizes, budgets and missions.

R&D in the European as well as international context is evaluated by means of not only individual indicators but also comprehensive indices based on a variety of selected factors of economic and social development (Halásková et al., 2016). The major indicator applied to compare the performance of innovation at the level of European countries is the Summary Innovation Index (SII). Part of the SII are also default indicators for public R&D (total R&D expenditures, R&D public expenditures or the number of publications (EC, 2016a). Innovation performance in EU countries with focus on the individual categories of innovators (Innovation Leaders, Strong Innovators, Moderate Innovators, Modest Innovators) is dealt with by Prokop, Stejskal (2017). The evaluation of R&D and key factors of innovation performance in EU countries are also addressed by other authors, e.g. Rodríguez-Pose, Crescenzi (2008).

Among the crucial indicators of a country's competitiveness are the total expenditures allocated on R&D. It is total expenditures of public and private sphere allocated to R&D in relation to GDP of a given economy. Total expenditures on R&D (GERD) include expenditures in four sectors of R&D (business enterprise, government, higher education, and private non-profit sector). The indicator of expenditures on R&D in relation to GDP enables a view on a country's innovation capacity and allows for assessing the effort of a country in generating new knowledge and using the results of research with verifiable positive externalities (OECD, 2015).

Other input R&D indicator are researchers. Number of R&D workers is usually measured by means of two basic units: a) total number of persons who are mainly or partially employed in R&D, this includes staff employed both full-time and part-time

and b) the recalculated number of people employed - full-time equivalent (FTE) in R&D (OECD, 2015). Apart from the expenditures on R&D (% GDP and researchers (FTE), also output indicators of R&D can be placed in the category, such as the number of scientific publications and citable publications. The output in the public sector is associated mainly with publications. Scientific publications include reviewed paper, book, chapter in a scientific book and article in a proceedings and are usually associated with public sector and with basic research, although new information about applied research is published as well (SJR, 2017). In publication results and in terms of citation-rate, the Hirsch index (H-index) plays a significant role. The H-index represents the volume of reactions to scientific papers published by a single scientist. It is a comprehensive indicator of citing rate as opposed to a mere citing response of a particular paper (Hirsch, 2005).

Public R&D tackles topical issues in relation to the efficiency of public expenditures in R&D, the position of public institutions, or the role of national R&D policies in the individual countries (Narin et al.,1997; Chiesa, Piccaluga, 2000; Guellec, Pottelsberghe De La Potterie, 2001; Cohen et al., 2002; Mazzoleni, Nelson, 2007; Corea, 2014; Becker, 2015; Halásková, Halásková, 2015). The structure and position of public research and mutual relations of R&D indicators are addressed by, e.g. David et al. (2000); Conte et al. (2009); Radosevic, Lepori (2009) or Steen (2012).

2 Methods

The paper makes use of data in a paper available at Eurostat (Statistic database - Research and Development) and Scopus database (Scimago Journal & Country Rank). The selected group comprises 28 EU countries (Belgium-BE, Bulgaria-BG, Czech Republic-CZ, Denmark-DK, Germany-DE, Estonia-EE, Ireland- IE, Greece-EL, Spain- ES, France-FR, Croatia-HR, Italy-IT, Cyprus-CY, Latvia-LV, Lithuania-LT, Luxembourg-LU, Hungary- HU, Malta-MT, Netherlands-NL, Austria-AT, Poland-PL, Portugal-PT, Romania-RO, Slovenia-SI, Slovakia-SK, Finland-FI, Sweden-SE, United Kingdom-UK). Key methods of the scientific work are: analysis, comparison and abstraction in the theoretical and methodological framework (correlation, factor, cluster analysis) and synthesis and partial induction in drawing conclusions. The intensity of R&D (total R&D expenditures as % of GDP) and R&D public expenditures as % of total R&D expenditures was analyzed in EU countries in years 2010 and 2015.

For comparing variables with different means and standard deviations z-scores were exploited to standardize raw scores, i.e. original values, assuming standardized normal distribution N (0, 1), where population means = 0 and standard deviation of the indicators = 1. Consequently, the z-score was calculated as follows:

$$z = \frac{x - \bar{x}}{s} \tag{1}$$

where: z is the z-score, x is the raw score, $\bar{x}$ is the mean of the sample, s is the standard deviation of the sample.

The empirical part applies transformed variables in year 2015: 1) R&D public expenditures as % of total R&D expenditures (**RDPE),** 2) Researchers (FTE) in public

sector as % of total researchers (FTE) (**RFTE**), 3) Number of publications per 1000 researchers (FTE) in public sector (**NPPS**), 4) Number of citable publications per 1000 researchers (FTE) in public sector **(NCP),** 5) measurement of public research quality-H-index per 1000 researchers (FTE) in public sector (**HI**).

The resulting Pearson correlation coefficient clearly confirms the dependence between input and output public research indicators (RDPE, RFTE, NPPS, NCP, HI), see Tab. 1. Rigours scrutiny of the scatter plots revealed influential outliers among three EU members, namely Bulgaria, Cyprus and Malta. Consequently, these three countries were excluded from the analysis, and results of the correlation measurements among the selected variables are presented for 25 EU countries.

Tab. 1: Correlations matrix public research indicators in the EU countries (2015)

	RDPE	**RFTE**	**NPPS**	**NCP**	**HI**
RDPE	1				
RFTE	0.837**	1			
NPPS	-0.711**	-0.739**	1		
NCP	-0.693**	-0.731**	0.995**	1	
HI	-0.168	-0.079	0.255	0.288	1

**Correlation is significant at the 0.01 level (2-tailed)

Source: Authors calculation

Hence, the explanatory factor analysis was implemented to deal with multicollinearity of these variables. Thus, the explanatory factor analysis explains the dispersion of the measured manifest variables. Factor analysis based on the correlation between a number of manifest variables determines whether some of them are close, i.e. whether they have one common factor (latent variable) or belong to another common factor (Košťál, 2013, p. 16). The results of the factor analysis detected one component (FAC1 – as public research includes RDPE, RFTE, NPPS and NCP) with standardized values employing principal factoring for estimation of factor loadings, i.e. the link between the latent factors and the original variables, and using the Cattell scree test plot and Kaiser's criterion on eigenvalues greater than 1 to determine those components with an eigenvalue larger than the average. Moreover, the explanatory factor analysis explained 83.9 % of the total variance within RDPE, RFTE, NPPS and NCP and the Kaiser-Meyer-Olkin measure of sampling adequacy reached value of 0.712 which provided the evidence for proceeding with the factor analysis.

Similarities and differences based on indicators of public research (FC 1- public research and HI) and development in EU countries in 2015 were evaluated by means of cluster analysis. Cluster analysis is a multi-dimensional statistical method used to classify objects. It enables sorting observed units into several groups so that similar units occurred in the same group, and, in turn, so that units from other groups differed fundamentally (Everitt, et al., 2011). Cluster analysis is used for the measurement of human development in EU countries e.g. Majerová, Nevima (2017). Thus, hierarchical tree diagram (i.e. dendrogram) is widely applied for depiction of final distances between objects. The horizontal axis of the dendrogram expresses distance between clusters. The vertical axis can determine the required extent of object clustering. Clusters unite based on the shortest distance, measured either with the Euclidean distance, or another, using any method of counting distance, such as average linkage, single linkage and complete

linkage. In our case, complete linkage method was implemented as clustering algorithm to perform hierarchical cluster analysis between two variables, i.e. standardized values of HI and FAC1 – Public research. This algorithm was determined by applying two cluster validation assessment techniques. 1) Cophenetic Correlation Coefficient (CCC) was used, for validating hierarchy of clustering schemes by measure and 2) Delta, was applied to measure the degree of distortion where the exponent is either 0.5 or 1 and values of this index close to zero are recommended (see Tab.2).

Tab. 2: Cluster validity assessment of agglomerative hierarchical clustering algorithms

Hierarchical algorithms	**CCC***	**$\Delta_{0.5}$****	**Δ_1****
Complete Linkage	0.79	0.35	0.39

*Cophenetic correlation coefficient; ** Delta

Source: Authors according to Halkidi et al, (2001);Mather(1976)

The EU countries were then compared using Box-plot, which is a form of graphic visualization of numerical data through their quartiles, dividing the statistical set into quarters, when 25% of items are below the values of the lower quartile *Q0.25* and 75% below the upper quartile *Q0.75.* The middle "box" of the diagram is delineated by the third quartile from the top, the first quartile from the bottom, and between those the line defining the *mean value* is found. The height of the box represents an *interquartile range.* The lower vertical line (lower whisker) corresponds with values found beneath the box. The end of the whisker corresponds with such lowest value from the set. Similarly, the upper whisker corresponds with the highest value from the set. Apart from whiskers (below and above them) are seen points which correspond with the so-called outliers (Pavlík, 2005). The data for the analysis of public research were generated with the IBM SPSS 25 software.

3 Results - Evaluation of Public Research Based on Selected Indicators

Public R&D in EU countries is analyzed with a particular focus on two key R&D indicators (total R&D expenditures as % of GDP and R&D public expenditures as % of total R&D expenditures, including their structure), and further similarities and differences of public research in EU countries are evaluated, using the example of selected indicators.

3.1 Total R&D expenditure and R&D public expenditure in EU countries

The indicator of the ratio of *total expenditures on R&D (GERD)* to GDP ("R&D intensity"), used most frequently in international comparison. GERD evaluates the implementation of targets of Europe 2020 strategy and the effort of the given country to generate new knowledge and the application of the outcome of research (OECD, 2015; European Commission, 2016b). More specifically, GERD are compared in the individual EU countries in 2010 and 2015 (Tab. 3). The higher these expenditures are, the better conditions they create for the growth and strengthening of the innovation potential. In 2015, the total expenditures on R&D accounted for approximately 2% on average in the EU 28, rising in comparison to 2010 (1.93%). Among countries with the highest total expenditures on R&D (% of GDP) in 2010 and 2015 are Scandinavian countries, Austria and Germany. Conversely, the lowest total expenditures on R&D (% of GDP) are seen in Cyprus, Romania, Latvia, Malta, Greece, and Bulgaria.

R&D public expenditures include R&D expenditures in the government sector (GOVERD) and R&D expenditures in the higher-education sector (HERD). As has been said, public expenditures are essential for the fulfillment of the Europe 2020 strategy in R&D. In 2010, countries with the highest intensity of public expenditures on R&D (% of GDP) were mainly Sweden and Finland (1.0%), followed by Denmark, Netherlands, Germany, and Austria, with expenditures around 0.9%. In 2015, due to an increasing role of the higher education sector, also the Czech Republic (0.88%) and Slovakia (0.85%) were added to the countries with the highest intensity of public R&D expenditures. A more detailed comparison of R&D public expenditures as % of total R&D expenditures in EU countries in 2010 and 2015 is seen in Tab. 3.

Tab. 3: Comparison of total R&D expenditures and R&D public expenditures in EU countries in 2010 and 2015

Country	Total R&D expenditures as % of GDP		R&D public expenditures as % of total R&D expenditure		R&D public expenditures (as % GOVERD and HERD)			
					GOVERD (%)		HERD (%)	
	2010	2015	2010	2015	2010	2015	2010	2015
BE	2.05	2.05	31.7	27.7	26	28	74	72
BG	0.56	0.96	50	26	75	80	25	20
CZ	1.34	1.95	41.7	45	52	45	48	55
DK	2.94	3.03	32.3	38	6	6	93	94
DE	2.71	2.87	32.8	32.4	45	46	55	54
EE	1.58	1.5	48.7	52	22	21	78	79
IE	1.6	1.51	31.2	21.8	16	15	84	85
EL	0.6	0.96	58.3	65.6	40	41	60	59
ES	1.35	1.22	48.1	46.7	42	40	58	60
FR	2.18	2.23	35.3	33.1	39	39	61	61
HR	0.74	0.85	56.7	49.4	50	50	50	50
IT	1.22	1.33	42.6	42	33	32	67	68
CY	0.45	0.46	68.8	65.2	29	20	71	80
LV	0.61	0.63	62.3	74.6	37	34	63	66
LT	0.78	1.04	71.8	73	25	24	75	76
LU	1.51	1.31	33.7	48.8	63	64	37	36
HU	1.15	1.38	38.2	25.3	48	51	52	49
MT	0.62	0.77	40.3	50.6	12	33	88	67
NL	1.72	2.01	52.3	44.7	22	28	78	72
AT	2.74	3.07	31	29	17	16	83	84
PL	0.72	1	73.6	54	49	46	51	54
PT	1.53	1.28	44.4	51.5	16	12	84	88
RO	0.45	0.49	62.2	57	61	68	39	32
SI	2.06	2.21	32	24	56	56	44	44
SK	0.62	1.18	56.4	72	51	39	49	61
FI	3.73	2.9	29.5	32.7	31	25	69	75
SE	3.22	3.26	31.3	30.3	16	11	84	89
UK	1.68	1.7	36.3	32.9	26	21	74	79
EU(28)	1.93	2.03	37.3	34.9	35	65	34	66

Source: Eurostat (2017) and authors' calculation

The share of public R&D resources (GOVERD+HERD) on total R&D expenditures (GERD) accounted for almost 35% in the EU 28 average in 2015, which, however, is approximately 3% less compared to 2010. Results in Tab. 3 show that in 2010 and 2015 R&D in the government sector and the higher-education sector plays an important role (accounting for no less than 40% share) in relation to total expenditure on R&D, mainly in 15 countries. Increase of R&D expenditures in the public sector in 2015, compared to 2010, is observed in eleven countries. The highest share of public expenditures as % of total R&D expenditure was observed in Poland (73.6%) and Lithuania (71.8%) in 2010, and Latvia (74.6%), Lithuania (73.0%) and Slovakia (72.0%) in 2015. The strongest position of the higher-education sector with respect to public R&D in EU countries in 2010 is seen in Denmark, Malta, Ireland, Sweden and Portugal, and in 2015 in Denmark, Ireland, Sweden, Portugal and Austria. Conversely, the public sector in terms of the public research plays a more prominent role mainly in Luxembourg, Poland, Hungary and Slovenia, mainly due to a strong position of institutions such as the academy of science, and in Bulgaria and Romania due to low R&D expenditures in the higher-education sector. Based on the results, it can be said that in the majority of the observed countries, public expenditures had increased and the role of the higher-education sector had strengthened in the structure of the public research in 2015, compared to 2010.

3.2 Evaluation of selected R&D indicators in EU countries

The R&D indicators (HI and FAC1 – Public research) were analyzed in 2015 through cluster analysis and box-plot in EU (25) countries. Out of the original 28 member states, three have been excluded from the evaluation (Bulgaria, Cyprus, Malta) on account of three outliers of R&D indicators, compared to other countries. Cyprus is the country with the highest number of publications (and citable publications) per 1000 researchers (FTE) in the public sector out of all EU countries and has also typically relatively high R&D public expenditures as % of total R&D expenditures and share of researchers (FTE) in the public sector as % of total researchers (FTE). Compared to other countries, it is a country with a low H-index value per 1000 researchers (FTE) in the public sector. Also Malta and Bulgaria have low H-index value per 1000 researchers (FTE) in the public sector. Malta and Bulgaria manifest a low number of publications per 1000 researchers (FTE) in the public sector. Bulgaria demonstrates the lowest number of citable publications per 1000 researchers (FTE) in the public sector, whereas Malta a high number of citable publications per 1000 researchers (FTE).

Results of the cluster analysis based on the indicators of public research (FAC1-Public research) and H-index in EU (25) countries divided into four clusters on the basis of internal similarity are shown in Tab. 4.

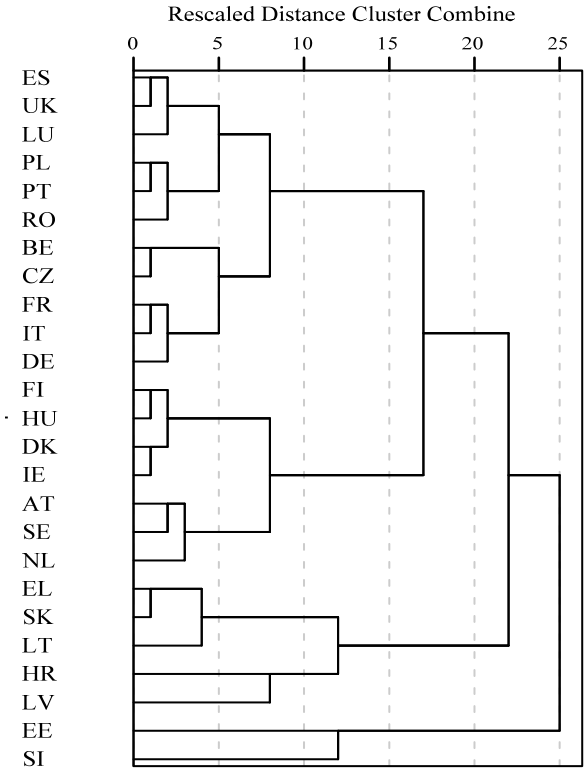
Tab. 4: Cluster membership according of indicators public R&D (2015)

First cluster	AT, HU, IE, NL, FI, DK, SE
Second cluster	BE, CZ, DE, ES, FR, LU, RO, UK, PL, PT, IT
Third cluster	EL, LV, LT, SK, HR
Fourth cluster	EE, SI

Source: Authors' calculation

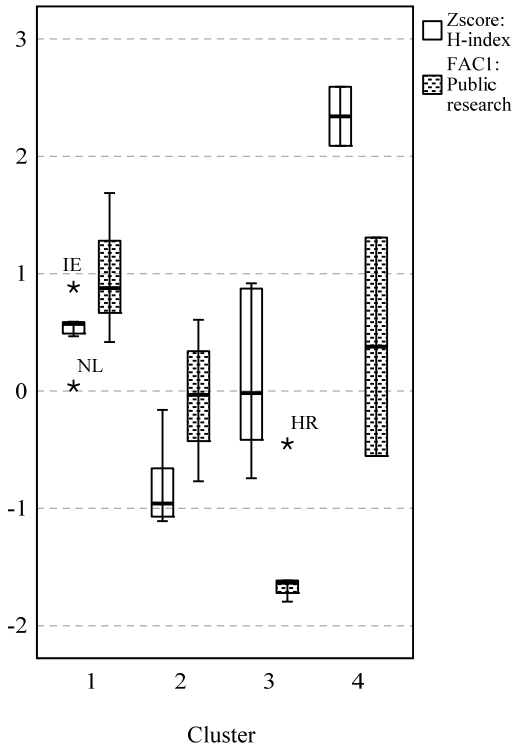
The EU countries are further analyzed on the basis of the selected indicators of public research, by used dendrogram (Fig.1) and the box-plot (Fig. 2.). The most marked differences, by indicators of public research, are seen in the countries in the first and third cluster, and the lowest median values of the H-index (HI) are seen in the countries in the second cluster, as opposed to the countries in the fourth cluster with the highest median values (Fig. 2).

Fig. 1: Dendrogram



Source: Authors

Fig. 2: Box – plot



Source: Authors

On the basis of the selected indicators of R&D policy, the highest similarity between the countries in the first cluster is seen in Ireland and Denmark (mainly in the number of researchers, number of publications, namely in cited publications per 1000 researchers, and the H-index). Large differences with outliers of the H-index values are apparent in two countries of the first cluster Ireland (value Z-score 0.92) and Netherlands (value Z-score 0.04). Another similarity is observed in Hungary and Finland in terms of the number of researchers (FTE) and H-index values.

The second cluster has the highest representation (eleven countries). The countries of the second cluster are characterized by a wide dispersion indicators of R&D in public research and H-index values. The strongest similarity of R&D policy is seen mainly in the couple Czech Republic and Belgium in the indicators of public research (researchers (FTE) in the public sector, the number of publications and citable publications per 1000 researchers (FTE)). BE reaches the highest values in the H-index in the countries of the second cluster. Other similarity is seen in Poland and Portugal in the indicators of public research, mainly in R&D public expenditure as % of total expenditure and the number of citable publications per 1000 researchers (FTE). In terms of all indicators of the public research, PT shows the lowest number of publications per 1000 researchers (FTE). Another similarity was found in Spain and

the United Kingdom in the H-index and indicators of public research in the number of researchers (FTE) in the public sector as % of total researchers. Out of all countries in the second cluster, IT reaches the highest number of publications and citable publications per 1000 researchers (FTE).

The third cluster shows the largest similarity, according to the selected R&D indicators, in Greece and Slovakia (in particular, in researchers (FTE) in the public sector and the number of publications and citable publications per 1000 researchers (FTE)). Another similarity in the indicators of public research is seen also in Lithuania and Latvia. A strong role of the public sector in R&D is in the countries of the third cluster, which are characterized by the highest public expenditures on R&D of total R&D expenditures, but also the highest representation of researchers (FTE) in the public sector of total researchers. By contrast, a weak role of the public sector in R&D is apparent in countries of the first cluster, with the lowest R&D public expenditures of total R&D expenditures and a low representation of researchers (FTE) in the public sector of total researchers. The fourth cluster is characterized by two countries (Slovenia and Estonia), with the highest H-index from all countries observed (the value of z score 2.1 in Slovenia, and 2.6 in Estonia. A lower similarity was seen in these countries in the indicators of public research, mainly in R&D public expenditure as % of total R&D expenditure, dominated by Estonia, as opposed to the number of publications and citable publications per 1000 researchers, dominated by Slovenia.

4 Discussion

The results of the analysis of the public research showed that seven EU countries with low R&D intensity (EL, CY, LV, LT, PL, RO) have a strong role of R&D public expenditures, between 60-70%. By contrast, eight countries (BE, DK, DE, FR, AT, SI, FI, SE) with the highest R&D intensity showed a weak role of R&D public expenditures in the public sector (approximately 30%). Also in researchers (FTE) in the public sector as % of total researchers was proved a strong representation and role of the public sector in six countries (BG, EL, HR, CY, LV, RO), around 70-85%. By contrast, in countries with a high R&D intensity (SE, FI, DK, DE, AT) was proved a weak representation of researchers (FTE) in the public sector as % of total researchers (approximately 30-40%), whereby the research question was answered, namely that the role of public R&D is more prominent in countries with lower R&D intensity, and vice versa. These results are also supported by the evaluation of public research in EU countries based on the selected indicators by use of cluster analysis and the box-plot, where a strong role of the public sector was observed in R&D in public expenditures as % of total R&D expenditures in countries of the third cluster (EL, LV, LT) a strong role of public research was also proved in the number of researchers (FTE) as % of total researchers in the public sector (EL and LV). In countries of the third cluster (EL, LV, LT, SK) the lowest number of publications (also citable publications) was found per 1000 researchers (FTE) in the public sector from all EU countries. By contrast, a weak role of the public sector in R&D was found in most countries of the first cluster (FI, DK, AT, SE), in the share of R&D public expenditures as % of total R&D expenditures, but also in the representation of researchers (FTE) (SE, FI, DK, AT). These differences can be explained by different national R&D policies, including their priorities, but also the position of the public and business-enterprise sector with respect to the Europe 2020 strategy (Albu, 2011, EC, 2016b, OECD, 2015). Differences in the evaluation of R&D

policy indicators are associated with a varying intensity of content-related priorities in research and development, since every single country creates its own concept of national policy in R&D (in 4-6 year perspective). Also, initial conditions and potential of the given state in terms of the development of science and research and innovation-related policy, requirement of the European research area (ERA) or the target connected with the fulfillment of the Europe 2020 strategy in R&D financing (fulfilled for a long time by some countries) need to be considered as well. Other causes of a different position are then connected with the structure and extent of research. Other causes of the varying position of countries are then connected with the structure and extent of research and science and innovation potential and the possibilities of its exploitation. The most efficient country, according to R&D indicators (output), in the EU is seen in Cyprus (in the number of publications per 1000 researchers (FTE) and their citing-rate). On the other hand, a low efficiency of R&D output (in publications and cited papers per 1000 researchers FTE) was found in most countries of the third cluster (EL, LV, LT, SK), which show the lowest numbers of publications and cited publications per 1000 researchers (FTE). Countries of the second cluster (EE, SI) dominate mainly in citing-rate by the individual authors, measured through H-index per 1000 researchers (FTE). According to the Halásková, Halásková (2015); OECD (2015); EC (2016b), the number of publications in relation to FTE researchers in R&D is a rough indicator of efficiency of research, which is why the quality of the papers needs to be considered as well, i.e. their citing rate. As stated in papers and studies (Hirsch, 2005; Conte et al., 2009), from the viewpoint of the efficiency of finances, mainly specific forms of results need to be observed as well as their quality or, alternatively, their potential for application. The quality of published results can be considered by the level of the journals (key is the order of the journals and their registration in renowned world databases) and citing rate, which often indicates the use of the information from other authors in associated research and development. As regards publications results, among the most appreciated are those reaching world quality (journals with high impact factor and the citing rate, H-index, etc.).

Conclusion

For the fulfillment of the Europe 2020 strategy in R&D, the improvement of conditions for financing research, development and innovations is stressed, when it is necessary to procure an adequate volume of financial resources from the public and the business-enterprise sector. It has been shown that in the countries of the EU (in 2015, compared to 2010) experience an increase in public expenditures on R&D, and mainly of the significance of the higher-education sector in the structure of the public research. Results of the analysis of the public research in EU countries showed a significant role of the public sector in R&D in Greece, Lithuania, Latvia, Cyprus, Malta, Croatia, Slovakia (evaluated by R&D public expenditures as % of total R&D expenditures and the share of researchers (FTE) in the public sector as % of total researchers). On the other hand, among countries with a low engagement of the public sector in R&D are Scandinavian countries and Austria. Differences in scientific activities were proved in EU countries, with respect to public research in connection to the priorities defined in national R&D policies. Public research in EU countries was analyzed through the selected indicators public research (financial, human resources and results) by means of cluster analysis and box-plot in 2015. Results of the present research confirmed the

differences in the scientific research activity and the use of the science-research potential. In terms of the 25 evaluated countries of the EU, the most marked differences were seen in the first and the third cluster of countries. By contrast, the most considerable differences in the H-index, which is related to the quality of citing-rate of publications and authors, were found in the countries in the second and fourth cluster.

The analysis of public research in the countries was carried out only using a limited number of R&D indicators (financial, human resources and results). A more in-depth analysis, including an evaluation of efficiency and quality of public research in the respective countries, would exceed the range of this paper. Another method for the evaluation of similarities and differences between EU countries is, for instance, multi-dimensional scaling. The use of a wider variety of indicators as well as the application of other methods (e.g. DEA) for quality assessment and the evaluation of R&D efficiency can be a theme for further research.

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References

Albu, N. (2011). *Research and Development Spending in the EU: 2020 Growth Strategy in Perspective. Working Paper FG 1, 2011/ No. 08*. Berlin: German Institute for International and Security Affairs.

Becker, B. (2015). Public R&D Policies and Private R&D Investment: A Survey of the Empirical Evidence. *Journal of Economic Surveys,* 29 (5), pp. 917-942. DOI: http://dx.doi.org/10.1111/joes.12074.

Cohen, W. M., Nelson, R.R., Walsh, J.P. (2002). Links and Impacts: The Influence of Public Research on Industrial R&D. *Management Science,* 48, (1), pp. 1-23. DOI http://dx.doi.org/10.1287/mnsc.48.1.1.14273.

Conte, A., Scweizer, P., Dierx, A. et al. (2009). An Analysis of the Efficiency of Public Spending and National Policies in the Area of R&D. *Occasional papers 54*. Brussels: European Commission.

Corea, P. (2014). *Public Expenditure Reviews in Science, Technology, and Innovation*. Washington, DC: The World Bank.

David, P. A., Hall, B. H., Toole, A. A (2000). Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence. *Research Policy,* 29 (4-5), pp. 497-529. DOI: http://dx.doi.org/10.1016/S0048-7333(99)00087-6.

Everitt, B., et al. (2011). *Cluster Analysis.* London: John Wiley & Sons.

Eurostat (2017). *Statistics Database- Research and Development.* [online] Available at: http://ec.europa.eu/eurostat/data/database>. [Accessed 15.8. 2017].

EC (2016a). *Innovation Union Scoreboard 2016.* [online] Available at: http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards/files/ius-2015_en.pdf>. [Accessed 23.8. 2017].

EC (2016b). *Science, Research and Innovation Performance of the EU.* Brussels: European Commission.

Guellec, D., Pottelsberghe De La Potterie, B. (2001). The Effectiveness of Public Policies in R&D. *Revue D'Economie Industrielle,* 94(1), pp. 49–68. DOI: http://dx.doi.org/10.3406/rei.2001.1780.

Halásková, M., Slovák, S., Halásková, R. (2016). Impact of Selected R&D Indicators on Competitiveness of the European Union Countries. In: *Proceedings of the 3rd International Conference on European Integration 2016.* Ostrava: VŠB- Technical University of Ostrava, pp. 309-318.

Halásková, M., Halásková, R. (2015). Research and Development Expenditure Assessment based on Selected Indicators in the EU Countries. In: *Proceedings of the 7th International Scientific Conference inance and the Performance of Firms in Science, Education, and Practice.* Zlín: UTB, pp. 342-357.

Halkidi, M., Batistakis, Y., Vazirgiannis, M. (2001). On Clustering Validation Techniques. *Journal of Intelligent Information Systems* 17(107), pp. 107-145. DOI: https://doi.org/10.1023/A:1012801612483.

Hirsch, J. E. (2005). An Index to Quantify an Individual's Scientific Research Output. *PNAS,* 102 (46), pp. 16569–16572. DOI: http://dx.doi.org/10.1073/pnas.0507655102.

Chiesa, V., Piccaluga, A. (2000). Exploitation and Diffusion of Public Research: The Case of Academic Spin-Off Companies in Italy. *R&D Management,* 30(4), pp. 329–340. DOI: http://dx.doi.org/10.1111/1467-9310.00187.

Koštál, J. (2013). *Vybrané metody vícerozměrné statistiky (se zvláštním zaměřením na kriminologický výzkum)*. Praha: Institut pro kriminologii a sociální prevenci.

Majerová, I., Nevima, J. (2017). The measurement of human development using the ward method of cluster analysis. *Journal of International Studies,* 10(2), pp. 239-257**.** DOI: 10.14254/2071-8330.2017/10-2/17.

Mather, P. M. (1976). *Computational Methods of Multivariate Analysis in Physical Geography*. Chichester: John Wiley & Sons.

Mazzoleni, R., Nelson, R. (2007). Public Research Institutions and Economic Catch-up. *Research Policy,* 36 (10), pp. 1512–1528. DOI: http://dx.doi.org/10.1016/j.respol.2007.06.007.

Narin, F., Hamilton, K., Olivastro, D. (1997). The Linkages between US Technology and Public Science. *Research Policy,* 26, pp. 317 330.

OECD (2015). *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development* [online] Available at http://www.keepeek.com/Digital-Asset-Management/oecd/science-and-technology/frascati-manual-2015_9789264239012-en#page1>. [Accessed 10.8. 2017].

Pavlík, J. (2005). *Aplikovaná statistika*. Praha: Vysoká škola chemicko-technologická.

Prokop, V., Stejskal, J. (2017). Different Approaches to Managing Innovation Activities: An Analysis of Strong, Moderate, and Modest Innovators. *Inzinerine Ekonomika – Engineering Economics,* 28 (1), pp. 47-55. DOI: http://dx.doi.org/10.5755/j01.ee.28.1.16111.

Radosevic, S., Lepori, B. (2009). Public Research Funding Systems in Central and Eastern Europe: between excellence and relevance: introduction to special section. *Science and Public Policy,* 36 (9), pp. 659–666. DOI: https://doi.org/10.3152/030234209X475236.

Rodríguez-Pose, A., Crescenzi, R. (2008). Research and Development, Spillovers, Innovation Systems, and the Genesis of Regional Growth in Europe. *Regional Studies,* 42 (1), pp. 51–67. DOI: http://dx.doi.org/10.1080/00343400701654186.

SJR(2017). *Scimago Journal & Country Rank* [online] Available at: http://www.scimagojr.com/countryrank.php. [Accessed 15.8. 2017].

Steen, J. (2012). Modes of Public Funding of Research and Development: Towards Internationally Comparable Indicators. *OECD Science, Technology and Industry Working Papers*, No. 2012/04. Paris: OECD Publishing.

Szarowska, I., Žurkova, D. (2017). Public Expenditure on Research and Development and its Relationship with Economic Growth in the Czechia, Denmark and Slovakia. *Scientific Papers of the University of Pardubice – Series D,* 24 (39/1/2017)), pp. 211-222.

Tkač, M., Spišaková, E. D., Gontkovičová, B. (2017). Research and Development in Slovakia, Denmark and Finland from the Perspective of the Strategy Europe 2020. *Scientific Papers of the University of Pardubice – Series D,* 24 (39 /1/2017)), pp. 223-235.

Contact Address

doc. Ing. Martina Halásková, Ph.D.
VŠB-Technical University of Ostrava, Faculty of Economics, Department of Public Economics
Sokolská třída 33, 701 21, Ostrava 1, Czech Republic
Email: martina.halaskova@vsb.cz
Phone number: +420597322315

RNDr. Pavel Bednář, Ph.D.
Tomas Bata University in Zlín, Faculty of Management and Economics, Department of Regional Development Public Administration and Law
Mostní 5139, 760 05, Zlín, Czech Republic
Email: bednar@fame.utb.cz
Phone number: +420576032841

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