

Diversification of the level and structure of research and development expenditure in the European Union countries

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Abstract

The purpose of the study is to assess the degree of the European Union (EU) countries' diversification in terms of the research and development intensity and the structure of R&D expenditure by the source of funding. The analysis includes R&D expenditure as % of the gross domestic product and the structure of R&D expenditure broken down by the following sectors: business enterprise, government, higher education, private non-profit and the "rest of the world", as well as changes in this area in the years 2008–2016. The research used multidimensional statistical analysis with particular focus on classification methods. The study results allowed separating the relatively homogeneous classes of the EU countries in terms of R&D intensity and structure of research and development expenditure by their funding sources.

Keywords: research and development expenditure, R&D intensity, source of R&D funds, the EU countries

JEL Classification: C19, F63, O52

1. Introduction

Nowadays innovation is considered one of the most important factors having impact on international competition and socio-economic development of countries and regions. It is the feature of economies presenting the capacity to create, implement and absorb innovations. "The research and development activity, defined as creative work, approached in a methodical way to increase the resources of knowledge (...) and to develop new applications for the existing knowledge, remains one of many types of innovative activities" (Manual, 2015, p. 28) and can constitute the source of innovation. R&D can be described taking into account its two correlated aspects: scale and results. It allows analysing both the size and the intensity of expenditure invested in research and development, the funding sources and the R&D effects (Dworak and Grzelak, 2010; Ostaszewska and Tylec, 2016). R&D activities represent an important economic problem analysed by many researchers. In addition, the subject literature discusses issues related to the cyclical nature of R&D (Mand, 2019; Ouyang, 2011), the effectiveness of incurred expenditure (Sawulski, 2018; McGrath and Romeri, 1994) as well as financing of R&D activities (Hall, 2009; Howell, 2017).

The European Union, recognising the importance of innovation, adopted the Europe 2020 development strategy, which defines the targets allowing the Member States to ensure smart development based on knowledge and innovation. Achieving this goal requires considerable expenditure on R&D and applying mechanisms facilitating the transfer of knowledge and tech-

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nology as well as absorbing innovation by the economy and enterprises. It is essential to monitor the realisation level of the targets set in the EU development strategy. The empirical research which was carried out follows this trend, focusing on the assessment of the diversification degree of the EU countries in terms of the intensity of R&D activity and the structure of research and development expenditure by their funding sources. The conducted analysis also covered the problem of changes occurring in this area.

2. Scope and methods of research

The subject of the analysis is the intensity and structure of expenditure on R&D activities by its funding sources in the European Union countries. Gross national expenditure on research and development covers all expenditure on R&D carried out on the territory of a given country in a given reporting period (GERD), including current and investment expenditure on R&D activity, but it does not include these funds' depreciation. The intensity of expenditure on R&D is defined as the ratio of internal expenditure on R&D against GDP (%).

The international research analysing expenditure incurred on R&D applies the classification of funding sources following the institutional classification in accordance with the Frascati Manual (Manual, 2015). There are 5 main funding sources of research and development activities, i.e.: business enterprise sector (BES), government sector (GOV), higher education sector (HES), private non-profit sector (PNP) and the rest of the world sector which covers institutions outside the territory of the country where R&D is carried out, including the EU institutions and bodies, international and supranational organizations regardless of the physical location of their offices or places of running a business. All the aforementioned sectors are, at the same time, the executors of R&D activities.

The data necessary to assess the intensity diversification and structure of R&D expenditure by its funding sources in the EU countries were retrieved from the Eurostat database. Based on the availability of statistical information, the research period covers the years 2008–2016.

The classifications of the EU countries were carried out using the following steps (the review of information on normalization methods, distance measures and classification methods can be found, e.g. in the studies by Hartigan (1975), Kukuła (2000)): determining the diversification among the analysed countries using the Euclidean Squared distance, hierarchical classification of countries using Ward's clustering method, identifying the number of classes based on the results of classifications presented on a dendrogram and the graph of fusion distance in the fusion stages, classification of countries using k -means method and the characteristics of the identified classes. In the case of the EU countries classification in terms of expenditure intensity on R&D, the output data were subjected to min-max normalization (Kukuła, 2000).

3. Diversification of the European Union countries in terms of the intensity of research and development activities

The strategic goal included in the Europe 2020 strategy is to allocate 3% of the EU GDP to investments in R&D. Fig. 1 presents the development of R&D intensity ratio in the EU as well

as the minimum and maximum values in the EU countries in the years 2008–2016. The average intensity of expenditure on R&D in the EU, in the analysed period, increased slightly, i.e. from 1.43% in 2006 to 1.55% in 2016, not reaching the target value. The lowest share of expenditure on R&D against GDP (approx. 0.40%) was recorded in 2008–2012 and in 2015 in Cyprus, in 2012–2013 in Romania and in 2016 in Latvia. The countries characterised by the highest intensity of expenditure on R&D include Finland (2008–2012, 2014), Sweden (2013, 2015–2016), where the share of expenditure exceeded 3%, ranging from 3.17 to 3.75 %.

The European Union countries were characterised by a very high diversification in the intensity of expenditure on research and development (see Tab. 1). However, in the analysed period the diversification intensity of R&D expenditure declined from approx. 62% to approx. 56%. The empirical range of the analysed indicator showed a right-sided symmetry, as the majority of countries presented lower than average shares of expenditure on R&D in GDP.

The composition of classes of the EU countries identified by the intensity of R&D expenditure and its characteristics are presented in Table 2 and on Figure 2. As a result of applying the *k*-means method 3 classes of countries, characterised by a relatively similar share of expenditure on R&D in GDP in 2008–2016, were identified. Class 1, including countries with the highest intensity of expenditure on R&D reaching, on average, approx. 2.74% of GDP was the least numerous. The class 3 covered 10 EU countries characterised by the mean share of expenditure on R&D in GDP (approx. 1.48%). From among the EU10 it included the Czech Republic, Estonia, Hungary. The class of countries featuring the lowest intensity of expenditure on R&D (approx. 0.69% with a slight upward trend) included 10 countries with only Greece from EU15.

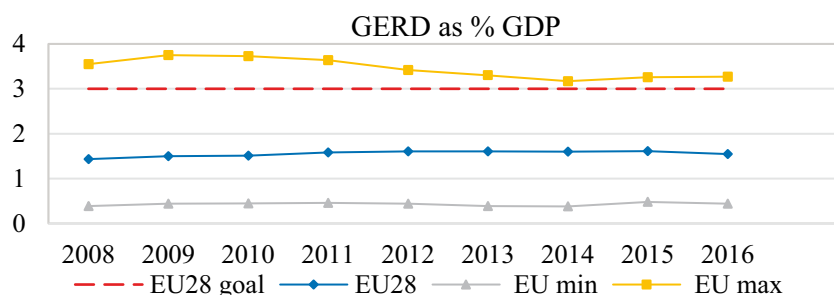


Fig. 1. The intensity of expenditure on R&D in the European Union countries in the years 2008–2016

Table 1. Descriptive parameters of the share of R&D expenditure in GDP in the EU28 in the years 2008–2016

Descriptive parameters	2008	2009	2010	2011	2012	2013	2014	2015	2016
Min	0.39	0.44	0.45	0.46	0.44	0.39	0.38	0.48	0.44
Max	3.55	3.75	3.73	3.64	3.42	3.30	3.17	3.26	3.27
Range	3.16	3.31	3.28	3.18	2.98	2.91	2.79	2.78	2.83

Descriptive parameters	2008	2009	2010	2011	2012	2013	2014	2015	2016
Mean	1.43	1.50	1.51	1,58	1.61	1.61	1.60	1.61	1.55
Median	1.29	1.38	1.43	1.46	1.34	1.36	1.35	1.31	1.27
CV (%)	62.43	62.80	59.98	57.92	56.55	55.63	54.13	52.47	56.87

where: CV – coefficient of variation

Class 1 of countries presenting high expenditure intensity on R&D in 2008 was characterised by the most extensive internal diversification (CV = 27.13%), which showed a declining tendency, reaching the value of 16.38% in 2016. In 2008 class 3 of the EU countries was characterised by the lowest dispersion (CV = 15.85%). However, in the analysed period the diversification of countries included in this class was continuously increasing, reaching 19.59% variability in 2018. Class 2 of countries with the lowest share of expenditure on R&D in GDP showed large diversification in 2008 (CV = 25.99%), indicating an increasing trend, in 2016 the CV coefficient reached the value of 27.76%. In 2016 it was the most diversified class of countries in terms of expenditure intensity on R&D.

Table 2. Classification of the European Union countries in terms of the share of R&D expenditure in GDP in the years 2008–2016 using *k*-means method

Class No.	GERD/GDP (%)	Countries (codes)*
1.	high	DK, DE, AT, FI, SE, BE, FR, SI
2.	low	BG, EL, HR, CY, LV, LT, MT, PL, RO, SK
3.	middle	CZ, EE, IE, ES, IT, LU, HU, NL, PT, UK

* codes for EU countries: Austria (AT), Belgium (BE), Bulgaria (BG), Cyprus (CY), Czech Republic (CZ), Germany (DE), Denmark (DK), Estonia (EE), Greece (EL), Spain (ES), Finland (FI), France (FR), Croatia (HR), Hungary (HU), Ireland (IE), Italy (IT), Lithuania (LT), Luxembourg (LU), Latvia (LV), Malta (MT), Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Sweden (SE), Slovenia (SI), Slovakia (SK), United Kingdom (UK)

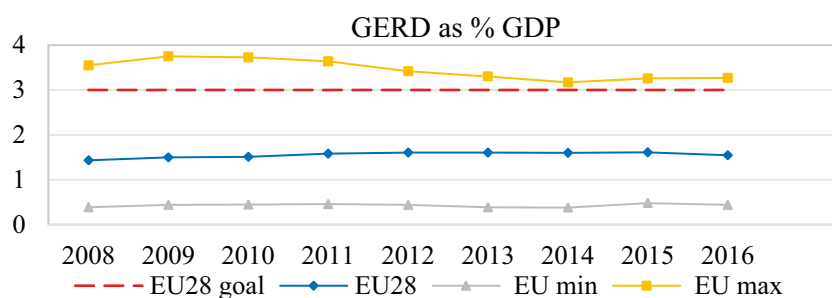


Fig. 2. Mean values of the share of R&D expenditure in GDP in the classes of the European Union countries identified using *k*-means method

In Poland, from 0.60% of GDP in 2008 up to 0.96% of GDP in 2016 was allocated to R&D in the analysed period. Therefore, Poland was assigned to the class of the EU countries characterised by low intensity of expenditure on research and development in the gross domestic product. In addition, as the national target of Europe 2020 strategy Poland declared reaching 1.7% level of R&D expenditure, which still remains a difficult challenge.

4. Classification of the European Union countries in terms of major funding sources of R&D activities

Tables 3 and 4 present the classification results of the European Union countries by the structure of expenditure on research and development by the funding sources in 2008 and in 2016, respectively. Fig. 3 shows dendrograms prepared using Ward's hierarchical clustering method and mean shares of R&D expenditure by the funding sources in both analysed periods, respectively. Based on the analysis of dendrograms and graphs of fusion distance in the fusion stages, the number of classes of the EU countries in 2008 and 2016 was determined as the basis for applying *k*-means method. Finally, the division of the European Union countries into 3 relatively homogeneous classes in 2008 and 4 classes in 2016 was performed.

Table 3. Classification of the European Union countries in terms of R&D expenditure structure by funding sources in 2008 prepared using *k*-means method

Class No.	GERD by source of funds	Countries	Mean share of R&D expenditure by funding sources (%)					Rest of the world
			BES	GOV	HES	PNP		
1.	Dominant share of BES	BE, DK, DE, LU, MT, SI, FI, SE	63.80	26.19	0.50	0.96	8.54	
2.	Dominant share of GOV	BG, EL, CY, LV, LT, PL, RO, SK	27.80	58.95	1.86	0.43	10.94	
3.	Balanced share of BES and GOV	CZ, EE, IE, ES, FR, HR, IT, HU, NL, AT, PT, UK	45.76	41.54	1.33	1.33	10.05	

The conducted empirical research shows that in 2008 BES and GOV sectors were definitely most involved in R&D activity funding in the EU countries. Their average total shares in R&D expenditure funding amounted to 89.99% in the first, 86.75% in the second and 87.30% in the third class of countries, respectively. The involvement of the rest of the world sector was also similar in all identified classes and ranged from over 8.50% in the first class to almost 11% in the second class. Another joint feature of the identified classes of countries was the marginal funding of R&D expenditure by HE and PNP sectors.

The main difference between the classes of countries identified in 2008 consists in a different degree of involvement of both business enterprise sector and government sector in R&D funding (see Fig. 3). The first class included 8 countries characterised by a dominant share of business enterprise sector in R&D expenditure funding (on average 63.80%), including only two countries from the EU10 group: Malta and Slovenia. Class 2 included countries where the government sector was the dominant one in R&D funding (58.95%). In this also 8-element class all countries except Greece belong to the EU10 group, the so-called countries of the new EU enlargement. These countries are characterised by low GDP per capita, among which there are Bulgaria, Romania and Poland. The characteristic feature of the countries included in class 3 is a relatively balanced share of both business enterprise and government sectors in R&D expenditure funding (45.76% and 41.54% respectively). It is the largest 12-element class in which EU15 countries predominate, but it also includes the Czech Republic, Estonia, Croatia and Hungary.

Table 4. Classification of the European Union countries in terms of R&D expenditure structure by funding sources in 2016 prepared using *k*-means method

Class No.	GERD by source of funds	Countries	Mean share of R&D expenditure by funding sources (%)				
			BES	GOV	HES	PNP	Rest of the world
1.	Dominant share of BES	BE, DK, DE, FR, HU, MT, NL, AT, SI, FI, SE, UK	57.51	28.59	0.63	1.68	11.55
2.	Dominant share of BES with high involvement of Rest of the world sector	BG, IE,	46.00	23.30	0.80	0.35	29.55
3.	Dominant share of GOV with high involvement of BES and Rest of the world sector	CZ, CY, LV, LT,	33.75	40.90	2.68	0.25	22.40
4.	Balanced share of BES and GOV	EE, EL, ES, HR, IT, LU, PL, PT, RO, SK	46.92	40.42	2.33	0.56	9.80

In 2016, 4 classes of countries featuring a different structure of R&D expenditure funding were identified. Similarly to the situation in 2008, all classes were characterised by a clear dominance of R&D expenditure funding by business enterprise and government sectors and the

lowest share of higher education and private non-profit sectors. However, in 2016 the classes of countries differed significantly between one other also regarding the involvement degree of the rest of the world sector. In 2016, as in 2008, the class of countries with a dominant share of the business enterprise sector (class 1) and a balanced share of the business enterprise and government sector in R&D expenditure funding (class 4) was distinguished. Class 1 included countries assigned to this class type in 2008 (excluding Luxembourg) and was extended by the following countries: France, Hungary, the Netherlands, Austria and the United Kingdom, which previously were characterised by a balanced involvement degree of BES and GOV sectors. Class 4 was enlarged by Poland, Romania and Slovakia, which in 2016 belonged to the group of countries with the dominant R&D funding from the government sources. In 2016 the class of countries characterised by the dominant share of BES (46%) and the large involvement of the rest of the world sector (29.55%) was identified and included only Bulgaria and Ireland (class 2). Class 3 was made up of the countries where the dominant source of funding was the GOV sector (40.9%), along with strong involvement of BES (33.75%) and the rest of the world sector (22.4%). In 2016 the Czech Republic, Cyprus, Latvia and Lithuania were characterised by such funding structure of R&D expenditure and, except for the Czech Republic, these countries also featured dominant GERD funding from the GOV sector in 2008, whereas the rest of the world was of minor importance (10.94%).

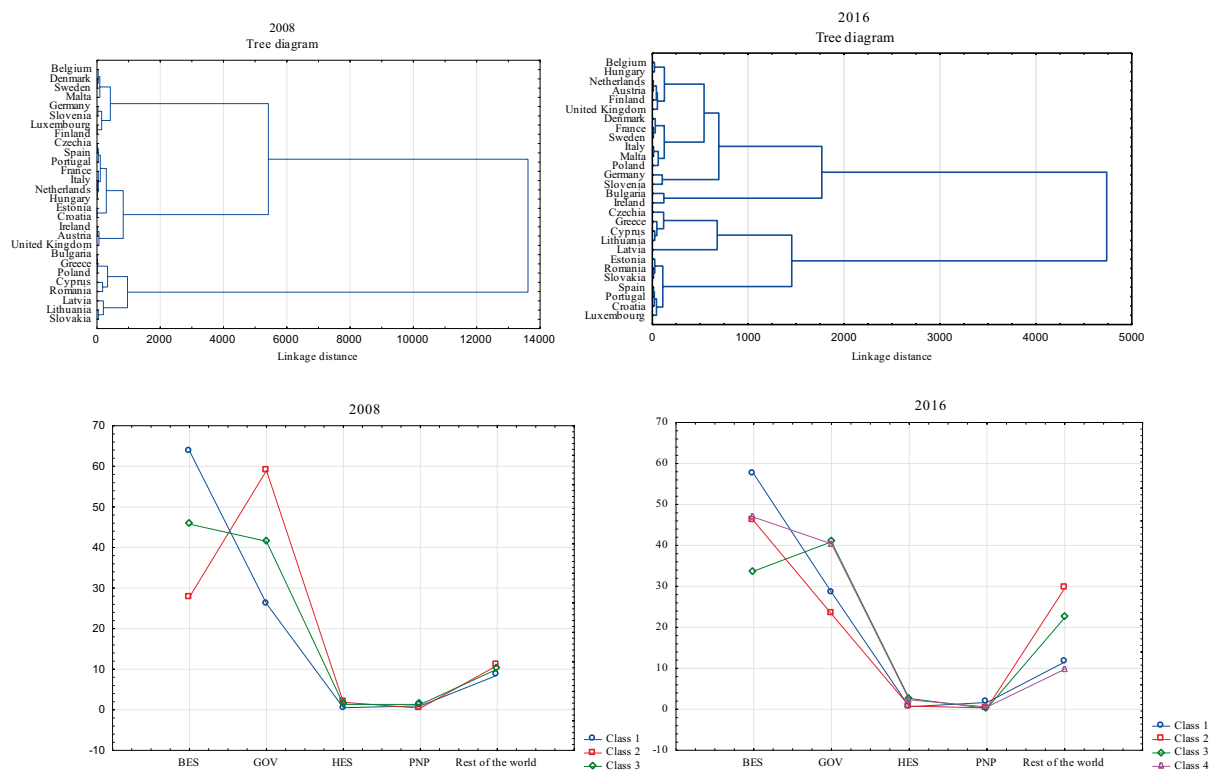


Fig. 3. Dendrogram prepared using Ward's method and mean shares of R&D expenditure by funding sources in the classes identified using *k*-means method in 2008 and 2016

Conclusions

The following conclusions can be presented on the basis of the conducted research:

1. The EU countries showed an extensive diversification throughout the entire analysed period in terms of R&D expenditure intensity, exceeding 50% variation. The tendency towards its reduction should be assessed positively (from approx. 62% to almost 56%). The discussed changes resulted from a slight decline in the intensity of R&D expenditure in the countries featuring the highest values (Finland, Sweden) and an increased share of R&D expenditure in GDP in the countries ranked as last in this respect (Cyprus, Romania, Latvia). In 2008–2016 the number of countries characterised by a lower than average intensity of R&D expenditure prevailed.

2. In the analysed period 3 separate groups of countries characterised by a different intensity of R&D expenditure were distinguished. The least numerous group included countries with a high share of expenditure on R&D in GDP. In the group of 10 countries featuring low intensity of R&D expenditure only Greece was included from the EU15 group, the remaining countries were the so-called new enlargement ones, including Poland.

3. The classification of the EU countries changed significantly in terms of R&D expenditure structure by the funding sources. In 2008 3 classes of countries with the dominant role of BES and GOV sectors and also their balanced share were distinguished, along with the similar significance of the other sectors. In 2016 two specific groups of countries were identified, which along with the dominance of BES sector (Bulgaria, Ireland) or GOV sector (Czech Republic, Cyprus, Latvia, Lithuania) were characterised by a large, amounting to 29.55% and 22.40% share of the rest of the world sector in funding R&D expenditure. More developed EU countries were characterised by higher intensity of R&D expenditure and greater involvement in R&D funding by the business enterprise sector.

Having recognised the importance of expenditure on R&D activities for the innovation and competitiveness of the EU countries, it is necessary to perform the ongoing monitoring of the occurring changes. In the long-term perspective it is worth carrying out in-depth research on the occurrence of club convergence, the crowding-out effect and the complementarity of private and public expenditures.

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