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EXPENDITURE ON RESEARCH AND DEVELOPMENT ACTIVITIES AS A DETERMINANT OF THE INNOVATIVENESS OF THE EUROPEAN UNION'S ECONOMY

NAKŁADY NA DZIAŁALNOŚĆ BADAWCZO-ROZWOJOWĄ JAKO DETERMINANTA INNOWACYJNOŚCI GOSPODARKI UNII EUROPEJSKIEJ

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Summary: This article aims to determine to what extent and with what time delay expenditure on research and development activity are determined by the effects of innovative activity. The accepted research hypothesis is that the positive impact of expenditure on research and development activity on its results is visible already after one or two years from when they were incurred. In order to empirically verify the proposed research hypothesis, the correlation between selected variables relating to R&D spending in 2013-2017 and selected variables determining the effects of innovative activity in 2018 in EU economies was examined. The results obtained in the study made it possible to verify the research hypothesis by confirming the important role of expenditure on research and development activity in the context of creating innovation of the economy, with particular emphasis on the financial resources of the private sector.

Keywords: research and development activity, innovativeness of the economy.

Streszczenie: Celem artykułu jest określenie, w jakim stopniu i z jakim opóźnieniem czasowym nakłady na działalność badawczo-rozwojową determinują efekty działalności innowacyjnej. Przyjęto hipotezę badawczą stanowiącą, że pozytywny wpływ nakładów na działalność badawczo-rozwojową na jej wyniki uwidacznia się już po roku lub dwóch latach od ich poniesienia. W celu empirycznej weryfikacji zaproponowanej hipotezy zbadano zależność korelacyjną między wybranymi zmiennymi odnoszącymi się do nakładów na działalność badawczo-rozwojową w latach 2013-2017 a wybranymi zmiennymi określającymi efekty działalności innowacyjnej w 2018 r. w gospodarkach unijnych. Uzyskane wyniki pozwoliły na pozytywną weryfikację postawionej hipotezy, potwierdzając ważną rolę nakładów na działalność badawczo-rozwojową w kontekście kreowania innowacyjności gospodarki, ze szczególnym uwzględnieniem środków finansowych sektora prywatnego.

Słowa kluczowe: działalność badawczo-rozwojowa, innowacyjność gospodarki.

1. Introduction

In today's conditions of globalization and intensifying competition on international markets, it is increasingly important to take care of undertakings that favor the achievement of competitive advantage over rivals. These certainly include research and development activity, which is an important determinant of innovation development, which in turn translates into the development of the entire economy. The increase in investment in research and development activity is reflected in an increase in work efficiency, as the same group of workers is able to produce more goods thanks to the introduction of new, more efficient production technologies. The importance of the development of research and development activity in the aspect of creating social and economic welfare is clearly understood by highly economically developed countries such as Sweden, the United States, Japan and South Korea. The level of expenditure on research and development activity in these countries is high and represents a significant share of gross domestic product. The effective management of the research and development area determines the technological progress, which results in the production of high added value. Investment in research and development activities may result in new or improved products, services, production processes, organizational and management methods, as well as technical and technological knowledge in the form of licences or patents.

Efficiently functioning research and development activities do not only require incurring appropriate financial outlays. The amount of capital involved is important but so is its structure and source of financing [Piątkowski 2010, p. 582]. The issue of financing research and development in the context of shaping the innovation of the economy of the European Union member states was emphasized in the European development strategies. According to the Lisbon Strategy, the private sector was obliged to bear 66% of the total expenditure on research and development, and the public sector 33%, assuming that the total percentage would amount to 3% of the country's GDP [Firlej 2016, p. 248]. These assumptions were not achieved during the Lisbon strategy implementation period and were maintained in the Europe 2020 strategy, which stressed both the need to increase private-sector R&D spending and to improve the conditions for private R&D activity in the European Union [Firlej 2013, p. 56]. The achievement of these objectives could enable a significant increase in the pace of innovation development at both European and national level. Taking into account the perspective of the Polish innovation policy, the appropriate construction of new support mechanisms, taking into account the market needs, should encourage the private sector to increase spending on research and development activity and consequently reflected in the assumed effects [Gasz 2015, p. 217].

2. Purpose, methodology and research area

This article aims to determine to what extent and with what time delay expenditure on research and development activity are determined by the effects of innovative activity. The accepted research hypothesis is that the positive impact of expenditure on research and development activity on its results is visible already after one or two years from when they were incurred.

The literature on the subject provides different results concerning the time shift for the mentioned dependency. An extreme case of such a shift can be indicated here, which may amount to several dozen years [Popp 2015] but the most common difference is two to five years. On the basis of empirical data for Japanese companies, Goto and Suzuki [1989] proved that two to five years must pass between incurring costs on research and development and the resulting sale of the product, depending on the sector of the economy. In contrast, Hsu et al. [2013] showed in a survey of Taiwanese companies that the positive impact of R&D spending on their revenues occurred after two years. Lykogianni and Verbeek [2008], on the other hand, based on regression analysis for data from 1980-2005 for the EU countries, Japan, and the USA, showed that the greatest positive impact of public R&D spending on the number of scientific publications and patent applications was recorded with a time delay of one or two years [Sawulski 2018, pp. 136-137]. Sawulski [2018] in a study on the effectiveness of R&D spending in Poland, compared to other EU member states, arbitrarily adopts the optimal size of the time shift to two years.

The article uses domestic and foreign literature, as well as statistical data published on the website of the European Statistical Office Eurostat and data presented in the report *Global Innovation Index 2019*. The data applies to all European Union member states in 2013-2018.

The Global Innovation Index is the result of cooperation between representatives of several entities, namely: Cornell University; INSEAD − the Business School of the World, a renowned management and business school; and the World Intellectual Property Organization (WIPO). The publication appears once a year. The latest edition of the report, dated 2019, includes 129 countries that have been ranked in terms of their economies' innovation performance. The Global Innovation Index consists of 80 individual indicators, which are divided into seven groups. Within each group of variables, three subgroups of indicators are additionally distinguished. All indicators are standardized using the min-max method and their value is between 0 and 100. Additionally, within the Global Innovation Index, two innovation sub-indexes are determined: the Innovation Input Sub-index and the Innovation Output Sub-Index. The latter sub-index has been used to conduct the research in this article. Innovation outputs are the results of innovative activities within an economy. Although the Output Sub-Index includes only two pillars, it has the same weight in calculating the overall GII scores as the Input Sub-Index. There are two output pillars: Knowledge and technology outputs and Creative outputs.

The paper first deals with the theoretical determinants of expenditure on research and development activities as a factor shaping the innovativeness of the economy. Then the analysis of empirical data concerning the following was performed: expenditure on research and development activity as a percentage of GDP in the European Union countries in 2013 and 2017, taking into account the structure of origin of these funds; participation of the private sector in financing research and development activity as a percentage of total expenditure for this purpose in the European Union countries in 2013 and 2016; the Global Innovation Index in 2019. Then, in order to empirically verify the research hypothesis proposed above using the *r*-Pearson correlation coefficient, the relationship between selected variables relating to R&D spending in 2013-2017 and selected variables determining the effects of innovative activity in 2018 in EU economies was examined.

3. Expenditure on research and development activity as a factor shaping the innovativeness of the economy

According to the latest edition of the Oslo manual [OECD 2018, p. 20] *an in-novation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes, and one that has been made available to potential users (product) or brought into use by the unit(process)*. Therefore, the term "innovation" is often referred to as a technical change [Solow 1957], which since the times of C.W. Cobb, P.H. Douglas and J. Hicks is identified with the shift in function resulting from the invention (or choice) of another production technique. In order to signal the wider than technological importance of innovation, with reference to J.A. Schumpeter, the following terms are also proposed: economic change [Nelson, Winter 1982] and entrepreneurial change [Godin 2008]. Despite the different contexts in which the terms are used, if one were to analyze the content of the definitions (through the production function) of these categories, it could be concluded that both Schumpeter's innovation, Solow's technical change and technical progress as understood by J. Hicks are factors that stimulate the productivity of the given factors of production – labour and (or) capital [Geodecki 2014, pp. 36-37].

A particularly important role in the process of creating an innovative economy is played by expenditure on research and development activities. This can be defined as creative work that is implemented in a methodical manner and carried out to increase knowledge resources of humankind, culture and society, as well as to create new applications for the existing knowledge [Central Statistical Office (GUS) 2018]. The results of R&D investments are highly volatile and subject to higher risks than fixed assets, although they are also the basis for long-term business benefits [Kothari et al. 2012, pp. 356-357]. Two groups are indicated among the factors motivating to finance and pursue R&D activity. The first covers economic determinants, which are reflected in the scale of research and development investments and are related,

among others, to the innovation policy pursued by the public sector (e.g. tax relief). The second group of management determinants covers the determinants within the company, including the company's strategy, human resources management, organizational culture, as well as other characteristics at individual level [Griffiths, Webster 2010, p. 471].

Expenditure on research and development activity performed at the stage of applied research are borne in particular by the private sector. This is mainly due to the fact that the transformation of inputs into outputs is faster and more predictable than in the case of fundamental research. On the other hand, regarding financing research and development activity at the stage of basic research, the public sector plays a special role due to the high risk and relatively long period of waiting for tangible research results in the form of the final product [Mikołajczyk 2018, p. 173]. State expenditure on research and development to a small extent participates in the structure of public spending, although it constitutes an important incentive for the private sector to incur expenditure for this purpose, and thus determines an accelerated increase in productivity and innovation, which consequently shapes economic growth [Ziółkowska 2016, pp. 87-108].

Research and development activity cannot, of course, be equated with innovation, nevertheless it is seen as a key element in relation to technological innovation in particular. As a result of research and development work, not only innovations are created, but also the company's ability to absorb knowledge from outside is increased [Klomp, Roelandt 2004, p. 368]. This is not only the case on a microeconomic scale, but also in a broader macroeconomic perspective. The ability to acquire new knowledge and new technologies results, at the level of the whole country or region, not only from local research and development activities, but also from the quality of higher education, the education of citizens, their openness and positive approach to innovative solutions. In the macroeconomic perspective, expenditure on research and development activity determine the reduction of the distance to the most developed economies in terms of innovativeness, and in the case of selected countries, the increase or maintaining a high level of development in the field of innovation [Patel, Pavitt 2000, p. 228].

4. Expenditure on research and development activity in the member states of the European Union

The level of expenditure on research and development as a percentage of GDP in individual EU countries in 2017 was very diverse, and the average for the European Union amounted to 2.06%. In relation to selected world economies, this result leaves much to be desired, as expenditure on research and development activity in Israel (4.3% of GDP), South Korea (4.2% of GDP), Japan (3% of GDP), Switzerland (3% of GDP), the United States (2.8% of GDP), Singapore (2.2% of GDP) or China (2.1% of GDP) is at a higher level [*The Global Competitiveness Report* 2018].

Due to the limited volume of this work, as well as the nature of the adopted research hypothesis, only data on total expenditure on research and development activities and those from the private sector were subjected to empirical analysis.

In 2017 the number of countries whose total R&D expenditure as a percentage of GDP was greater than 3% increased to four, i.e. Sweden (3.4%), Austria (3.16%), Denmark (3.05%) and Germany (3.02%). Besides these countries, Finland (2.76%), Belgium (2.58%) and France (2.19%) achieved better results than the EU average (2.06%). On the other hand, the weakest results were observed in Romania (0.5%), Latvia (0.51%), Cyprus (0.56%), Bulgaria (0.75%), Croatia (0.86%), Slovakia (0.88%) and Lithuania (0.89%). In relation to the average total expenditure on research and development activities in the European Union, for six countries these results were better, and for 22 countries – worse. In relation to 2013, the number of countries with less expenditure than the EU average (as a percentage of GDP) increased. The comparison of the results from 2017 with the results from 2013 shows an increase in total R&D expenditure as a percentage of GDP in 15 countries, a decrease in 12 countries and no change in one country [Eurostat 2019].

In 2017 the number of countries where the level of expenditure of the private sector on R&D as a percentage of GDP exceeded the 2% threshold did not change in relation to 2013, namely: Sweden (2.42%), Austria (2.22%) and Germany (2.09%). Results exceeding the EU average (1.36%) but at the same time lower than 2% were observed in five countries: Denmark (1.97%), Finland (1.8%), Belgium (1.76%), France (1.42%) and Slovenia (1.39%). Nevertheless, it can be noted that Finland, France and Slovenia obtained worse results than they did in 2013. The lowest share, below the 0.5% threshold, of the private sector in expenditure on research and development activities as a percentage of GDP was observed in the following countries: Latvia (0.14%), Cyprus (0.2%), Romania (0.29%), Lithuania (0.32%), Malta (0.34%), Croatia (0.42%) and Slovakia (0.48%). The analysis of private sector expenditure on research and development as a percentage of GDP in the European Union in 2017 indicates that in relation to the EU average (1.36%), only eight countries achieved better results and as many as 20 countries achieved weaker results. Therefore no changes in comparison to 2013 were recorded. Comparing the 2017 and 2013 results shows that expenditure of the private sector on research and development as a percentage of GDP increased in 19 countries, decreased in eight countries and remained unchanged in one country [Eurostat 2019].

The participation of the private sector in financing research and development activities as a percentage of total expenditure for this purpose in the European Union countries did not undergo any dynamic changes and in 2013 and 2017 was similar (EU 28 average – 55.2% and 56.6%). The highest indicators in the analyzed period were obtained by Slovenia, Germany, Belgium, Denmark, Sweden and Finland. The results of all these countries were better than the EU average in both years analyzed. On the other hand, among the countries with the lowest share of enterprises in expenditure on research and development activity as a percentage of total expenditure

for this purpose in 2013 were: Cyprus (15.8%), Luxembourg (16.5%), Bulgaria (19.5%), Latvia (21.8%) and Lithuania (27.5%). In 2017, in turn, the lowest result was achieved by: Latvia (21.6%), Cyprus (34.9%), Lithuania (39%) and the Czech Republic (39.3%). Overall, in 2017, compared to 2013, the ratio increased in 22 countries and decreased in six countries [Eurostat 2019].

Table 1. Innovativeness of European Union member states according to the Global Innovation Index 2019

Country	Global Innovation Index	Global Innovation Output Sub-Index	Knowledge and technology outputs	Creative outputs
EU 28	49.14	41.11	39.9	42.3
Belgium	50.18	39.63	40.8	38.5
Bulgaria	40.35	32.61	31.4	33.8
Czech Republic	49.43	43.44	43.8	43.1
Denmark	58.44	47.55	46.4	48.6
Germany	59.19	51.1	52.7	49.6
Estonia	49.97	43.83	36	51.7
Ireland	56.1	50.08	56.9	43.3
Greece	38.9	27.61	25.1	30.1
Spain	47.85	38.42	37.2	39.7
France	54.25	45	45	45
Croatia	37.82	28.28	25.6	31
Italy	46.3	37.87	38.9	36.8
Cyprus	48.34	41.13	41.2	41.1
Latvia	42.23	35.17	27.5	42.8
Lithuania	41.46	32.34	24.4	40.3
Luxembourg	53.47	49.2	42.2	56.2
Hungary	44.51	38.67	42.8	34.6
Malta	49.01	43.44	31.9	55
Netherlands	61.44	57.49	61.8	53.2
Austria	50.94	39.06	36.7	41.4
Poland	41.31	31.66	30.9	32.4
Portugal	44.65	34.6	29.8	39.4
Romania	36.76	28.02	30.03	25.8
Slovenia	45.25	36.4	30.7	42.1
Slovakia	42.05	35.55	34	37.1
Finland	59.83	51.62	55.1	48.1
Sweden	63.65	56.87	61.8	51.9
Great Britain	61.3	54.38	56.6	52.2

Source: own study based on [*Global Innovation Index 2019...*].

The indicators presented so far are related to expenditure on research and development activities, with particular emphasis on the importance of financing such undertakings by the private sector. The intention to carry out research into the correlation between R&D spending in its various dimensions and the broadly understood effects in the area of innovation activity makes it necessary to cite the indicators set out in the Global Innovation Index.

According to the latest edition of the report (2019), the most innovative economies in the EU are Sweden, the Netherlands and the United Kingdom. These countries achieved the best results in comparison with the European Union in terms of total innovation, the effects of innovative activity, as well as knowledge and technological achievements. In the case of creative production, these countries also recorded excellent results, however slightly overtaken by Luxembourg and Malta (Table 1).

Selected results were calculated on the basis of quantitative data of particular variables. In all cases of investigated correlations, the number of pairs of variables was equal to the number of EU member states and amounted to $N = 28$. Due to the need to take into account time delays, the survey used statistical data from 2013-2017 (control variables) and 2018[1] (response variables), (Table 2).

Table 2. Correlation matrix of the value of the *r*-Pearson correlation coefficient of selected variables relating to R&D spending and selected variables relating to the effects of innovative activity in the member states of the European Union

Control variables	Year	Response variables		
		Global Innovation Output Sub-Index	Knowledge and technology outputs	Creative outputs
Total expenditure on research and development activity as a percentage of GDP	2013	0.64	0.63	0.50
	2014	0.62	0.63	0.47
	2015	0.60	0.61	0.45
	2016	0.60	0.62	0.43
	2017	0.58	0.61	0.41
Expenditures of the private sector on research and development as a percentage of GDP	2013	0.61	0.62	0.44
	2014	0.59	0.62	0.42
	2015	0.58	0.61	0.40
	2016	0.58	0.62	0.40
	2017	0.57	0.62	0.38
Share of the private sector in financing research and development activities as a percentage of total expenditure for this purpose	2013	0.47	0.53	n. c.
	2014	0.52	0.49	0.43
	2015	0.47	0.48	0.36
	2016	0.36	0.39	n. c.
	2017	n. d.	n.d.	n. d.

n.c. – no correlation; n.d. – no data.

Source: own calculations and studies.

[1] *The Global Innovation Index 2019* includes results in the field of innovation of countries obtained in 2018.

As a result of quantitative research on the level of the *r*-Pearson correlation between selected variables concerning R&D spending in 2013-2017 and selected variables concerning the effects of innovative activity (values of variables according to the Global Innovation Index 2019 report) in the EU member states ($N = 28$). a high or average level of dependence was observed in most of the years covered (Table 2).

The highest level of correlation was identified in the case of the variable total expenditures on R&D activity as a percentage of GDP in the European Union countries. and the effects of innovative activity (sub-indicator within GII 2019). for which ($r = 0.58$-0.64; $p < 0.01$) depending on the assumed time delay. A high level of correlation ($r = 0.57$-0.61; $p < 0.01$) was also observed in the case of the private sector research and development spending variable as a percentage of GDP in the European Union countries and with the effects of innovative activity. A lower level of correlation than the aforementioned cases was obtained between the variable share of the private sector in the financing of research and development activity as a percentage of total outlays for this purpose in the European Union countries and the effects of innovative activity. In this case. the highest level of correlation achieved ($r = 0.52$; $p < 0.01$) was recorded for a four-year time delay. A slightly lower average level of dependence was obtained taking into account a time delay of three or five years ($r = 0.47$; $p < 0.025$). Regarding a two-year time delay. the correlation ($r = 0.36$) is statistically significant for $p < 0.1$ (Table 2).

In the case of the variable knowledge and technological achievements (group 6 within GII 2019) and its control variables. i.e. total outlay for R&D activity as a percentage of GDP and private-sector R&D spending as a percentage of GDP. a similarly high level of correlation was obtained ($r = 0.61$-0.63; $p < 0.01$) in the first case and ($r = 0.61$-0.62. $p < 0.01$) in the second case. A smaller but also more important role in terms of the impact on the value of the knowledge and technological achievements variable was played by the variable share of the private sector in financing R&D as a percentage of total expenditure on R&D in the European Union countries. This dependence can be defined as high when taking into account five years of time delay ($r = 0.53$; $p < 0.01$) or the average for three to four years of time delay ($r = 0.48$-0.49; $p < 0.025$). However. in the situation of a two-year time delay. the correlation ($r = 0.36$) is statistically significant for $p < 0.1$ (Table 2).

The variable of creative production was correlated to the greatest extent with variables of total R&D spending as a percentage of GDP in 2013 ($r = 0.5$; $p < 0.01$) and private-sector R&D spending as a percentage of GDP in 2013 ($r = 0.44$; $p < 0.025$). In both cases. one can talk about an average level of correlation. Taking into account shorter time delays. an even lower average level of correlation can be observed in both cases. Between the variable share of the private sector in financing research and development as a percentage of total outlays and the variable of creative production. a significant statistical average correlation was shown only for this share in 2014 ($r = 0.43$; $p < 0.05$) and 2015 ($r = 0.36$; $p < 0.1$) (Table 2).

5. Conclusion

On the basis of the analysis carried out in the area of expenditure on research and development activity as determinants of innovation of the European Union economy. the following research conclusions can be presented:

1. Expenditure incurred on research and development activity has a high impact on the effects of innovative activity with particular emphasis on the effects in the area of knowledge and technological achievements. A slightly smaller causal role should be assigned to that expenditure in the context of creating creative production. The effects of financing research and development activity are visible already after the first year since they were incurred and show a growing tendency over the years.

2. The structure of financing research and development activity is reflected in the effects of innovative activity to a lesser extent than the level of expenditure incurred. Participation of the private sector in expenditure on research and development activity has shown an average but close to a high positive impact on shaping the effects of innovative activity. in particular the results in terms of knowledge and technological achievements. These effects could be observed already after two years. while the optimum level was formed after four to five years. On the other hand. the share of private resources in financing R&D is moderately reflected in the shaping of creative production after three to four years.

3. The assumptions concerning the financing of research and development activity presented in the European development strategies should be regarded as appropriate and constituting the foundation for building the innovation of the European Union economy. It should be remembered. however. that the necessity of waiting (sometimes several years) for the achievement of measurable effects of the incurred expenditure on research and development activity requires patience from both the private and governmental sectors.

4. The chances of achieving the objectives of the Europe 2020 strategy in terms of the amount of funding for research and development activity by European Union member states. as well as their sources of origin. are small due to the approaching end of the period of its implementation. In many countries of the European Union there is limited scope for raising such expenditure. Therefore an important task for innovation policy should be not only to propose instruments stimulating the increase of expenditure on research and development activity but also to ensure maximizing their effectiveness.

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