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Public debt marriage with R&D management in the V4 and EU-27 countries in the context of the COVID-19 pandemic

Abstract

The aim of the article was to identify the relationship between the value of public debt and selected effects of research and development in the V4 and EU-27 countries, while taking into account the possible impact of the COVID-19 pandemic. Due to the breadth of issues related to the R&D sphere, 2 predictors were identified. The first is R&D expenditure, and the second is the number of employees with higher education employed in R&D. Statistical data analysis was used as a method of collecting and developing the empirical data. The practical implication of the study is to show that both before and in the first year of the pandemic, the relationship between public debt and research, and development activity in the V4 and EU-27 countries was strong, which justifies the in-depth monitoring and study of this relationship in subsequent years of the pandemic.

Keywords: public debt, R&D management, Pearson correlation, V4, EU-27

JEL Classification: O320

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Introduction

Nowadays, there is a significant increase in public debt in many European countries (Eurostat, 2022). The very issue of public debt began to be analyzed in the 1990s. This was especially true of post-communist countries such as Poland, Hungary, the Czech Republic and Slovakia. In each of these countries, the amount of public debt (especially when approached in absolute terms) has been growing dynamically since 1996 (Eurostat, 2022). This aspect may lead to numerous dangers related to the functioning of the state, its financial problems being the first serious hazard. In recent years, the solution to this problem has not been facilitated either by the COVID-19 pandemic (what even exacerbated the problem) or by the war between Russia and Ukraine.

As, on the one hand, research and development is one of the main engines of economic development and the creation of a modern knowledge-based economy (conditioning the efficient use of natural resources and limiting the negative impact on the environment) and - on the other hand - the issue of public debt itself has a large group of supporters and opponents, it was decided to combine these two aspects in one study.

An interesting research problem was the question whether public debt contributes to the implementation of R&D activities. Therefore, this article aims to identify the relationship between the value of public debt and selected indicators of research, and development activity in the V4 and EU-27 countries, while taking into account the possible impact of the COVID-19 pandemic. For this purpose, in the empirical part of the study, an analysis of Pearson's correlation between the amount of public debt and arbitrarily selected measures of research and development activity was carried out.

In the course of the research procedure, the following research hypotheses were formulated:

- Hypothesis (H1) assumes that public debt has a significant impact on the R&D expenditure of the V4 and EU-27 countries, both before and during the COVID-19 pandemic.
- Hypothesis (H2) assumes that there is a relationship between the number of employees with higher education employed in R&D and the public debt of the V4 and EU-27 countries, before the pandemic begins and also in the first year of its duration.

1. Public debt and research and development activities - theoretical analysis

1.1. The public debt

Various definitions of public debt can be found in the literature. For P.A. Samuelson and W.D. Nordhaus, it is […] *the entirety of government obligations in the form of bonds and shorter-term loans. Government debt does not include bonds held by quasi-governmental agencies such as the Central Bank* (Samuelson, & Nordhaus, 2004, p. 578-579).

According to the International Monetary Fund, these are exactly the financial liabilities of the government sector (International Monetary Fund, 2014, p. 36). There are two definitions of the described issue in the structures of the European Union. Both of them are included in the Council Regulation of November 22, 1993 on the application of the protocol on the excessive deficit procedure annexed to the Treaty establishing the European Community (EC No. 3605/93) and in Council Regulation (EC) No. 2223/96. In the first document it was specified that public debt is total gross debt in nominal value present at the end of the year and combined for the public sector. This debt includes deposits, cash, securities and stocks. Partly in contrast to the above explanation, it is possible to find two fundamental differences in the other document, the Council Regulation (EC) No 2223/96. According to this document, public debt has a broader structure, as it additionally includes stocks and other shares, as well as all other technical provisions. Therefore, the rates are higher. The form of valuation is also different here, where the market method was adopted.

In Polish legislation, public debt is perceived as *[…] nominal debt of public finance sector entities, established after eliminating flows between entities belonging to this sector* (Act, 2009). In turn, in the Polish scientific literature this issue was described, among others, by E. Chojna-Duch, who stated that these are *[…] the total financial liabilities of public sector entities due to various from an economic and legal point of view legal and financial events, and above all - shortages resulting from financing a surplus of public expenditure over accumulated public revenue in previous periods; these obligations should take into account their consolidation, that is, the elimination of mutual financial flows between them* (Chojna-Duch, 2012, pp. 273-274).

1.2. R&D activities

Research and development can be defined as systematic work that has been undertaken to increase knowledge about culture, man and society, and to search for completely new solutions to this knowledge (Central Statistical Office, 2022). M. Morawski and G. Kobyłko (2006, p. 201) defined R&D as systematic and planned creative work carried out in order to increase the amount of knowledge and its implementation in innovative applications.

In order for a research project to be carried out, there is a need for appropriate staff. It consists of, among others, researchers and project managers. J. Kisielnicki (2019, p. 27) observes that such projects are one of the most interesting and ambitious challenges for all teams involved in their implementation. The implementing staff, and especially the management staff (project managers), can demonstrate high and unique qualifications in the implementation of research and development tasks. Research and development projects also require the use of *[…] very specific management methods and techniques, such as knowledge management* (Foss, Pedersen et al., 2012, pp. 198-213).

To carry out research and development activities and to implement innovations, highly qualified employees are needed - their number on the market is limited, while employment costs are high. The limited number of professionals shows the direct importance of the mobility of people involved in technology transfer processes.

J. Kisielnicki (2017) added that among the methods of project management, the following are important:

- knowledge, competency and talent management;
- ability to use information and communication technology, including MIS (Management Information Systems) methods and BI (Business Intelligence) systems.

It is worth emphasizing that people involved in R&D in many cases hold academic degrees or are at the stage of obtaining them. The objects of their interest are projects characterized by scientific elements (the use of methods and principles of scientific research).

Among the organizations implementing research and development in Poland, the following can be distinguished (Marek & Białasiewicz, 2011, p. 96):

- public and private universities carrying out R&D activities;
- research centers of the Polish Academy of Sciences;
- science service units (e.g. archives, research libraries);
- research and development units (e.g. Road and Bridge Research Institute, Institute of Non-Ferrous Metals, etc.).

It can be emphasized that one of the external factors determining the implementation of R&D activities are financial resources and access to external financing sources (cf: Lesakova, Wolak-Tuzimek et al., 2016, pp. 209-259). The significant role of financial resources increases the probability of successful implementation of results. This will be manifested by organizations with (even short-term) financial surpluses or having staff with knowledge and skills in the field of obtaining, among others, government funds (e.g. EU funds).

In the case of EU funds allocated to the implementation of R&D projects, Czekański & Gajek, 2015, pp. 68-69 specify the following eligible costs:

- staff costs: researchers, technicians and other support staff to the extent that they are employed on the research project;
- costs of instruments and equipment to the extent and for the period used for the project. If the apparatus and equipment are not used for the project throughout its useful life, only the depreciation costs corresponding to the duration of the project, calculated on the basis of good accounting practice, are eligible costs;
- costs for buildings and land to the extent and for the period used for the project. For buildings, only the depreciation costs corresponding to the duration of the project, calculated on the basis of good accounting practice, are eligible costs. For land, the eligible costs shall be the transfer costs on a commercial basis or actual capital costs incurred.
- costs of contractual research, knowledge and patents purchased or used under a license granted by external sources at arm's length, and costs of consultancy and equivalent services used solely for the project.
- additional overhead costs incurred directly as a result of the project implementation.
- other operating expenses, including costs of materials and similar products incurred directly as a result of the project.

Therefore, it can be agreed that financial resources are one of the most important factors in the implementation of R&D projects. Without them, it is difficult to recruit qualified staff or create appropriate infrastructure and research equipment.

2. Public debt and R&D in the V4 and EU-27 countries - statistical data analysis

2.1. The public debt

In many European countries, public debt tended to increase, but it is worth noting that this was not the case in all of them. In tab. 1 shows the amount of public debt in the countries of the Višegrad Group and the EU-27 in 2010-2020.

Table 1. Public debt in relation to GDP in the countries of the Visegrad Group and the EU-27 in 2010-2020 (in%)

Year	UE-27	The Czech Republic	Hungary	Poland	Slovakia
2010	80,4	37,1	80,0	53,5	40,8
2011	81,7	39,7	80,3	54,7	43,3
2012	85,0	44,2	78,1	54,4	51,9
2013	86,7	44,4	77,2	56,5	54,9
2014	86,8	41,9	76,5	51,1	53,7
2015	85,0	39,7	75,7	51,3	51,8
2016	84,2	36,6	74,8	54,2	52,4
2017	81,6	34,2	72,1	50,6	51,6
2018	79,6	32,1	69,1	48,8	49,6
2019	77,5	30,1	65,5	45,6	48,1
2020	90,0	37,7	79,6	57,1	59,7

Source: own elaboration on the Eurostat (2022) data base.

It can be observed that the ratio of public debt to GDP in the V4 had the lowest rates in the case of the Czech Republic. In 2010, it was 37.1% of GDP and by 2019 this value had dropped to 30.1% of GDP. Poland and Hungary also recorded a decrease in this indicator between 2010 and 2019. In the case of Slovakia, public debt in 2010 was 40.8%, while in 2019 it was 48.1%. In 2019, the EU-27 had a public debt to GDP ratio of 77.5%. In 2020, in each analyzed case, this indicator increased, which was undoubtedly the result of the COVID-19 pandemic. At that time, government support for enterprises was launched in order to save economies. The European Commission has provided EUR 1 billion from the European Fund for Strategic Investments. This support is to be a guarantee for the European Investment Fund. Thanks to this, efforts were made to encourage banks and other lenders to guarantee financial liquidity of at least 100,000. European enterprises (cf. Malawski, 2013, pp. 62-65).

On April 6, 2020, the Commission announced that around EUR 8 billion will be made available to provide immediate financial assistance to small

and medium-sized enterprises across the EU. In December 2020, the Commission said the creation of a EUR 25 billion pan-European guarantee fund, managed by the European Investment Bank, will support companies affected by the coronavirus (European Commission, 2022).

P. Della Posta *et al.* (2004, p. 18) argued that the political responses of the EU institutions were important for a more sustainable public debt; this opinion is especially true for a highly indebted country such as Italy. In fact, the first major decision made by EU policymakers was to suspend the rules of the Stability and Growth Pact.

C.A. Patillo *et al*.(2004, pp. 18-19) conducted a study in which they found that public debt affected the economies of 61 developing countries in the years 1996–1998. The results proved that, for example, the cost of limiting the accumulation of physical capital has a negative impact on economic growth.

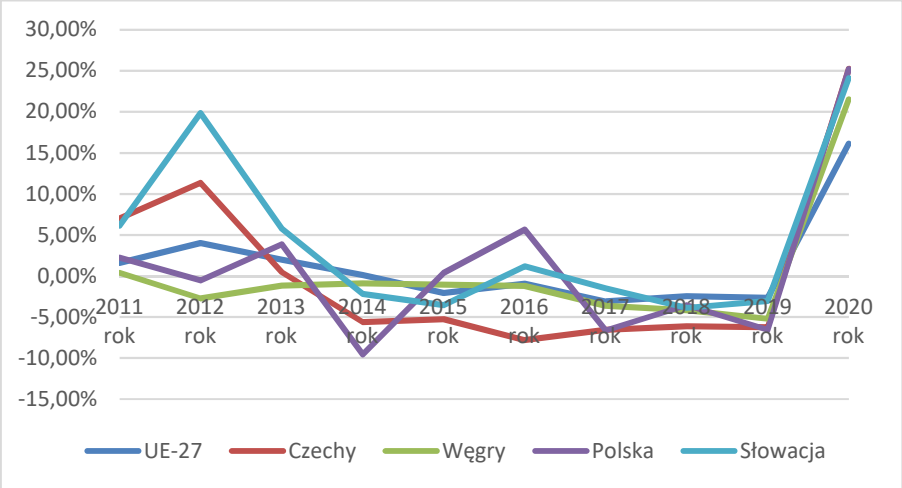

Figure 1. Dynamics of changes in public debt in relation to GDP in the countries of the Visegrad Group and the EU-27 in 2010-2020 (in%)
Source**:** Own elaboration

In turn, A. Alfonso & J. Alves (2014, p. 2), using selected indicators for 155 countries, examined the relationship between economic growth, production and public debt. It was found that debt had a negative impact on both GDP and economic growth. At the same time, the financial crisis slowed down economic growth and fiscal consolidation stimulated growth.

The analysis of changes in public debt in the V4 and EU-27 countries is complemented by the depiction of the dynamics of changes for this indicator (Fig. 1).

According to the data presented in Fig. 1, the largest increase in public debt between 2019 and 2020 concerned the Czech Republic and Poland. It was 25.25% and 25.22%, respectively. In Slovakia, an increase was recorded at the level of 24.12%, while in Hungary - 21.53%. In the EU-27, this value was 16.13%. Taking into account the fact that the V4 and EU-27 countries showed a downward trend since 2017, it can be noticed how destructive the crisis caused by the pandemic was for the economies.

2.2. R&D expenditure

The next issue to be analyzed is the expenditure on R&D in the V4 and EU-27 countries (Table 2). In turn, Fig. 2 shows the dynamics of changes in R&D expenditure in the V4 and EU-27 countries.

Table 2. Expenditure on R&D in the Visegrad Group countries and the EU-27 in 2010-2020 (in million euro)

Rok	UE-27	The Czech Republic	Hungary	Poland	Slovakia
2010	216 262,08	2 095,14	1 126,07	2 607,51	416,37
2011	228 346,01	2 551,99	1 204,63	2 836,17	468,44
2012	236 674,97	2 877,26	1 257,33	3 429,85	585,23
2013	241 491,75	2 996,67	1 415,10	3 436,28	610,88
2014	248 550,43	3 090,66	1 428,82	3 864,02	669,63
2015	258 745,82	3 250,24	1 510,94	4 316,51	927,27
2016	265 704,38	2 963,27	1 371,67	4 112,35	640,84
2017	281 437,40	3 433,34	1 672,95	4 834,04	748,96
2018	295 742,92	4 006,46	2 051,38	6 018,49	750,95
2019	311 891,50	4 348,35	2 158,62	7 046,92	776,59
2020	311 149,57	4 285,86	2 196,41	7 292,84	838,93
Mean	263 272,44	3 263,57	1 581,26	4 526,81	675,82

Source: own elaboration on Eurostate (2022) data base.

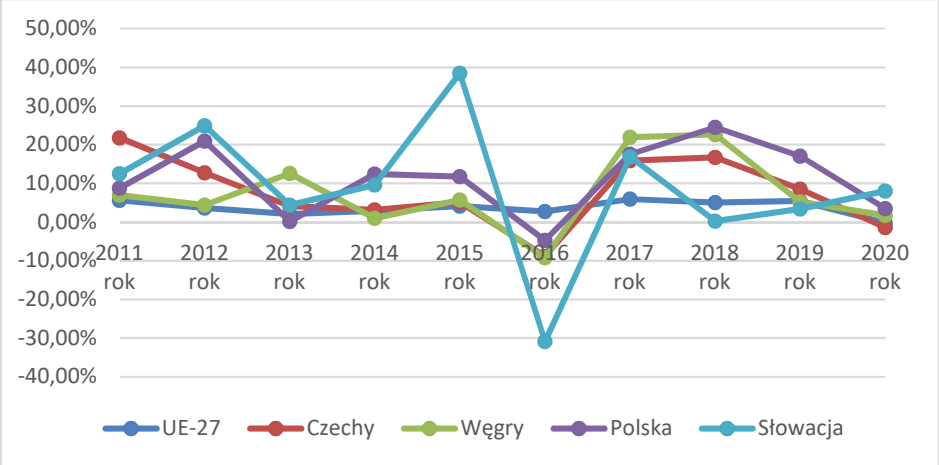

Figure 2. Dynamics of changes in R&D expenditure in the Visegrad Group countries and the EU-27 in 2010-2020 (%)
Source: Own study.

In the V4 countries, Poland had the highest R&D expenditure, on average it was approximately EUR 4.53 billion. The Czech Republic was second in this respect, which allocated an average of EUR 3.26 billion to research and development. Slovakia was the worst with EUR 675.82 million. The average in the EU-27 in 2010-2020 was EUR 263.27 billion. Importantly, the COVID-19 pandemic in this case did not have an impact, and if so, it did not affect R&D expenditure in the analyzed countries. However, this situation may be the result of previously planned and allocated research funds. Therefore, the impact of the coronavirus on this indicator may be visible in the coming years. Interestingly, back in April 2020, the US government wondered how COVID-19 would affect this sphere. It was noted that the implementation of the social distancing guidelines led to the closure of many laboratories and R&D projects. Even in the case of continued R&D projects, the effects of a pandemic can affect the efficiency and quality of this activity, for example through additional costs and challenges such as the closure of suppliers and service providers. D. Romer (2000, pp. 377-378) explains in detail the topic of the cost of using capital. Some resources devoted to ongoing research and development are also diverted to work focused on COVID-19 (cf: Morgan & Sargent Jr., 2020). A similar situation took place in the European Union (Böhme, Zillmer *et al*., 2022).

2.3. Number of employees employed in the R&D sector

As mentioned earlier, adequate financial resources are provided by, inter alia, qualified staff that can be employed in specific R&D projects. In tab. Fig. 3 presents data related to the number of employees with higher education employed in research and development activities in the V4 and EU-27 countries in 2010-2020, and Fig. 3 shows the dynamics of changes in this indicator.

Table 3. Number of employees with higher education employed in research and development activities in the V4 and EU-27 countries in 2010-2020 (in thousands)

Year	UE-27	The Czech Republic	Hungary	Poland	Slovakia
2010	75 633,7	1 906,3	1 305,4	5 633,3	845,9
2011	77 145,9	1 795,6	1 382,7	5 755,9	843,4
2012	78 950,1	1 835,9	1 438,7	5 959,2	813,5
2013	80 133,7	1 887,3	1 473,7	6 176,6	805,8
2014	82 313,4	1 921,5	1 528,9	6 497,2	818,6
2015	84 332,5	1 931,0	1 568,6	6 734,6	847,2
2016	86 580,2	1 990,5	1 594,5	6 896,3	876,0
2017	88 845,2	2 060,0	1 611,7	7 145,5	913,0
2018	91 116,5	2 101,4	1 659,5	7 338,3	960,7
2019	93 491,0	2 093,4	1 716,3	7 429,3	1 000,1
2020	94 371,0	2 117,0	1 783,6	7 521,3	1 022,6
Mean	84 810,3	1 967,3	1 551,2	6 644,3	886,1

Source: own elaboration on the Eurostat 2022 data base.

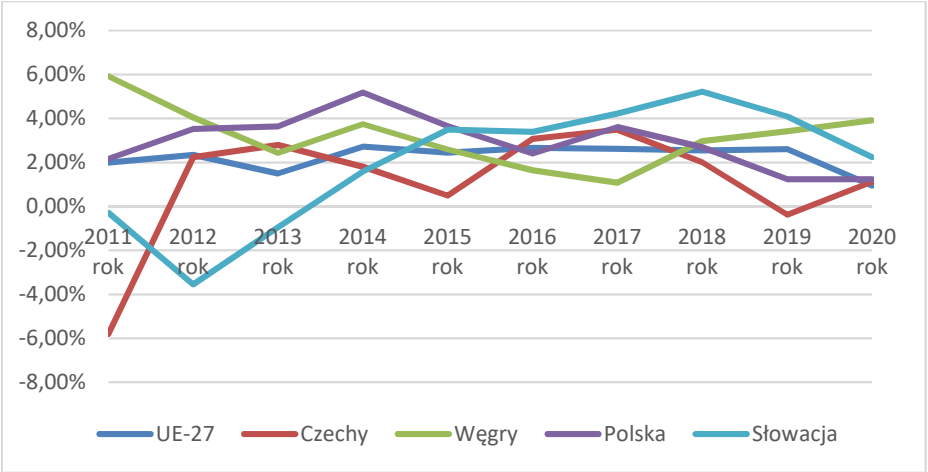

Figure 3. Dynamics of changes in the number of employees with higher education employed in research and development in the V4 and EU-27 countries in 2010-2020 (in %)
Source: own study

The highest average number of employees with higher education employed in the research and development sector in the V4 countries in 2010-2020 was in Poland, and it was 6.64 million people. The remaining countries had significantly lower rates, however, it should be noted that Poland from this group is also the most populous country. The average for the EU-27 was 84.81 billion people. The dynamics of changes in the described index was characterized by fluctuations for each of the analyzed countries. As in the case of R&D expenditure, also in this case no major negative changes were observed between 2019 and 2020. In the V4 and EU-27, an increase in the number of employees was observed in relation to the aforementioned years.

3. The relationship between the value of public debt and selected indicators of R&D activity - correlation analysis

Pearson's correlation was used in the analysis of dependencies. It was assumed that:

- 0 - 0.3 will mean no or very weak correlation;
- 0.3 - 0.5 will be a moderate correlation;
- 0.5 - 0.7 will prove a strong correlation;
- 0.7 - 1 will be characterized by a very strong correlation.

3.1. Public debt and R&D expenditure

The first two variables examined were the value of public debt and R&D expenditure in 2019, i.e. before the outbreak of the COVID-19 pandemic (Table 4) and in 2020, i.e. in the first year of the pandemic (Table 5).

Table 4. The relationship between public debt and R&D expenditure in the Visegrad Group countries and the EU-27 in 2019

Country	Public debt	R&D expenditure	$Y_i - \bar{Y}$	$X_i - \bar{X}$	$(y_i-\bar{y})(x_i-\bar{x})$	$(X_i - \bar{X})^2$	$(y_i-\bar{y})^2$
	Y_i	X_i					
UE-27	77,50	311891,50	24,14	246647,10	5954060,99	60834791938,41	582,74
The Czech Republic	30,10	4348,35	-23,26	-60896,05	1416442,12	3708328905,60	541,03
Hungary	65,50	2158,62	12,14	-63085,78	-765861,37	3979815638,21	147,38
Poland	45,60	7046,92	-7,76	-58197,48	451612,44	3386946678,35	60,22
Slovakia	48,10	776,59	-5,26	-64467,81	339100,68	4156098526,20	27,67
	∑ 267	**∑ 326222**	**X**	**X**	**7395354,87**	**76065981686,77**	**1359,03**

Source: own elaboration and calculations.

Mean values

$\bar{y}=(\sum y_i)/N = 267/5 =$ **53,36**

$\bar{x}=(\sum x_i)/N = 326222/5=$ **65244,4**

Standard deviations

*Sy = √(∑ ⟦(y_i-ȳ)⟧ ^2/N) = √(1359,03/5)=√271,81=***16,49**

Sx = √(∑ ⟦(x_i - x̄)⟧ ^2/N) = √(76065981686,77/5)= √15213196337,35 = **123341,79**

Covariance

cov*(y,x) = (∑ ⟦(y_i - ȳ)(x_i - x̄) ⟧)/N =* 7395354,87/5 = **1479070,97**

Correlation coefficient

*r_yx=(cov(y,x))/(S_y*S_x)=1479070,97/(16,49*123341,79)=* **0,73**

Table 5. The relationship between public debt and R&D expenditure in the Visegrad Group countries and the EU-27 in 2020

Country	Public debt Y_i	R&D expenditure X_i	$Y_i - \bar{Y}$	$X_i - \bar{X}$	$(y_i-\bar{y})(x_i-\bar{x})$	$(X_i - \bar{X})^2$	$(y_i-\bar{y})^2$
UE-27	90	311 149,57	25,18	245 996,85	6194200,633	60514449226	634,0324
The Czech Republic	37,7	4 285,86	-27,12	-60 866,86	1650709,297	3704774890	735,4944
Hungary	79,6	2 196,41	14,78	-62 956,31	-930494,2914	3963497221	218,4484
Poland	57,1	7 292,84	-7,72	-57 859,88	446678,289	3347765945	59,5984
Slovakia	59,7	838,93	-5,12	-64 313,79	329286,615	4136263841	26,2144
	∑ 324,1	**∑ 325763,61**	**X**	**X**	**7690380,543**	**75666751123**	**1673,788**

Source: own elaboration and calcuations.

Mean values

$\bar{y} = (\sum y_i)/N = 324,1/5 =$ **64,82**

$\bar{x} = (\sum x_i)/N = 325763,61/5 =$ **65152,72**

Standard deviations

$Sy = \sqrt{(\sum [(y_i-\bar{y})]^2/N)} = \sqrt{(1673,79/5)} = \sqrt{334,76} =$ **18,30**

$Sx = \sqrt{(\sum [(x_i-\bar{x})]^2/N)} = \sqrt{(75666751123/5)} = \sqrt{15133350225} =$ **123017,68**

Covariance

$\text{cov}(y,x) = (\sum [(y_i-\bar{y})(x_i-\bar{x})])/N =$ 7690380,54/5= **1538076,11**

Correlation coefficient

$r_{yx} = (\text{cov}(y,x))/(S_y * S_x) = 1538076,11/(18,30*123017,68) =$ 0,68

The correlation coefficient between the amount of public debt and R&D expenditure in 2019 was *r* = 0.73. Thus, the correlation turned out to be positive. The relationship, on the other hand, was very strong. The analysis carried out on the data from 2020 showed that *r* = 0.68. There was also a positive correlation in this case, and the relationship between the studied variables should be considered strong. This shows how the pandemic situation influenced the relationship between public debt and R&D expenditure in the Visegrad Group countries and the EU-27.

3.2. The public debt relation to the number of employees employed in R&D

The next stage of the research was devoted to examining the relationship between the value of public debt and the number of employees with higher education employed in research and development activities in the Visegrad

Group countries and the EU-27 in 2019, i.e. before the start of the COVID-19 pandemic (Table 6) and in 2020 ie after the outbreak of the pandemic (Table 7).

Table 6. Relationship between public debt and the number of employees with higher education employed in research and development in the Visegrad Group countries and the EU-27 in 2019

Country	Public debt	Number of employees with higher education employed in R&D	$Y_i - \bar{Y}$	$X_i - \bar{X}$	$(y_i-\bar{y})(x_i-\bar{x})$	$(X_i - \bar{X})^2$	$(y_i-\bar{y})^2$
	Y_i	X_i					
UE-27	77,50	93 491,00	24,14	72 344,98	1746407,817	5233796131	582,7396
The Czech Republic	30,10	2 093,40	-23,26	-19 052,62	443163,9412	363002328,9	541,0276
Hungary	65,50	1 716,30	12,14	-19 429,72	-235876,801	377514019,3	147,3796
Poland	45,60	7 429,30	-7,76	-13 716,72	106441,7472	188148407,6	60,2176
Slovakia	48,10	1 000,10	-5,26	-20 145,92	105967,5392	405858092,6	27,6676
	∑ 267	**∑ 105730**	**X**	**X**	**2166104,2**	**6568318980**	**1359,032**

Source: own elaboration and calculations.

Mean values

$$\acute{y} = \frac{\sum y_i}{N} = \frac{267}{5} = 53{,}36$$

$$\acute{x} = \frac{\sum x_i}{N} = \frac{105730}{5} = 21146{,}02$$

Standard deviations

$$S_y = \sqrt{\frac{\sum(y_i-\bar{y})^2}{N}} = \sqrt{\frac{1359{,}032}{5}} = \sqrt{271{,}81} = 16{,}49$$

$$S_x = \sqrt{\frac{\sum(x_i-\bar{x})^2}{N}} = \sqrt{\frac{6568318980}{5}} = \sqrt{1313663796} = \mathbf{36244{,}5}$$

Covariance

$$cov(y,x) = \frac{\sum(y_i-\acute{y})(x_i-\acute{x})}{N} = \frac{2166104{,}24}{5} = 433220{,}85$$

Correlation coefficient

$$r_{yx} = \frac{cov(y,x)}{S_y * S_x} = \frac{433220{,}85}{16{,}49 * 36244{,}5} = 0{,}72$$

Table 7. Relationship between public debt and the number of employees with higher education employed in research and development activities in the Visegrad Group countries and the EU-27 in 2020

Country	Public debt	Number of employees with higher education employed in R&D	$Y_i - \bar{Y}$	$X_i - \bar{X}$	$(y_i-\bar{y})(x_i-\bar{x})$	$(X_i - \bar{X})^2$	$(y_i-\bar{y})^2$
	Y_i	X_i					
UE-27	90	94 371,00	25,18	73 007,90	1838338,922	5330153462	634,0324
The Czech Republic	37,7	2 117,00	-27,12	-19 246,10	521954,232	370412365,2	735,4944
Hungary	79,6	1 783,60	14,78	-19 579,50	-289385,01	383356820,3	218,4484
Poland	57,1	7 521,30	-7,72	-13 841,80	106858,696	191595427,2	59,5984
Slovakia	59,7	1 022,60	-5,12	-20 340,50	104143,36	413735940,3	26,2144
	∑ 324	**∑ 106816**	**X**	**X**	2281910,2	6689254015	1673,788

Source: own elaboration and calculations.

Mean values

$\bar{y} = (\sum y_i)/N$ = 324/5 = **64,82**

$\bar{x} = (\sum x_i)/N$ = 106816/5 = **21363,1**

Standard deviation

$Sy = \sqrt{(\sum [(y_i-\bar{y})]^2/N)} = \sqrt{(1673,788/5)} = \sqrt{334,7576}$ = **18,29638**

$Sx = \sqrt{(\sum [(x_i - \bar{x})]^2/N)} = \sqrt{(6689254015/5)} = \sqrt{1337850803}$ = **36576,64**

Covariance

$\mathrm{cov}(y,x) = (\sum [(y_i - \bar{y})(x_i - \bar{x})])/N$ = 2281910,2/5 = **456382,04**

Correlation coefficient

$r_{yx} = (\mathrm{cov}(y,x))/(S_y * S_x) = 456382,04/(18,29638*36576,64)$ = **0,68**

The correlation coefficient between the value of public debt and the number of employees with higher education employed in research and development in the Visegrad Group countries and the EU-27 in 2019 was y = 0.72. The correlation turned out to be positive in this case as well. The relationship, however, should be interpreted as very strong. The analysis carried out on the data from 2020, i.e. after the outbreak of the pandemic, shows that r = 0.68. This should be seen as a positive correlation, and the relationship between the variables studied turned out to be strong again.

Conclusions

The constantly increasing public debt must be properly managed and controlled. Such actions can lead to certain situations that the ordinary citizen may not feel, but can experience significant economic and social consequences in the long run.

If the specified ceiling is exceeded, there is a real risk of a financial crisis, which will result in an increase in unemployment and reduction of expenditure (e.g. in the area of education, research subsidies, etc.). Such an approach may lead not only to the fact that a given country will not be able to compete on the market, but it will also stop developing, the GDP (Gross Domestic Product) will fall and the economic growth will slow down.

During the research procedure, the following research hypotheses were identified:

- Hypothesis (H1) assumed that public debt has a significant impact on the R&D expenditure of the EU-27 and V4 countries before and during the COVID-19 pandemic.
- Hypothesis (H2) assumed that there is a relationship between the number of employees with higher education employed in R&D and the public debt of the EU-27 and V4 countries, before the pandemic begins and also in the first year of its duration.

Basing upon the research presented above the following conclusions can be drawn:

1. Along with the increase in public debt, R&D expenditures increased both before and in the first year of the COVID-19 pandemic in the Višegrad Group countries and the EU-27.
2. Along with the increase in public debt, there was observed an increase in the number of employed workers with higher education in research and development activities before and in the first year of the COVID-19 pandemic in the V4 and EU-27 countries.

Considering the above, it can be concluded that the empirical analysis made it possible to achieve the assumed research goal and also to positively verify both research hypotheses. However, the considerations as proposed should be considered only as pilot ones. Numerous research limitations did not allow us to propose final recommendations. The conducted research is only a contribution to further in-depth analyzes in the future.

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