

R&D EXPENDITURE IN CHALLENGING ECONOMIC TIMES. RESULTS FROM THE VISEGRAD GROUP COUNTRIES

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Purpose: The aim of the paper is to examine how R&D expenditure differs among the Visegrad Group countries in challenging economic environment.

Design/methodology/approach: The research uses a comparative analysis, zero unitarization method and a multivariate analysis. The application of these methods allows the division of the Visegrad Group countries according to the level of the R&D expenditure variables. The research is based on Eurostat data. The research period was 2011–2022, when the Visegrad Group countries faced inflationary pressure and the covid pandemic.

Findings: The results show a relatively high diversity among the Visegrad Group countries in terms of R&D expenditure. Czechia and Poland stand out with a very high level of R&D expenditure variables, which may indicate a high capacity for innovation and resilience despite challenging economic circumstances.

Research limitations/implications: The study has some limitations that could be areas for future research. As the study focuses on R&D expenditure by sector (in relation to gross domestic product) and on intramural R&D expenditure in the business enterprise sector and the government sector (in relation to total expenditure), it would be valuable to investigate whether the results obtained also hold for other measures of R&D expenditure. It might also be worthwhile to examine how the Visegrad Group countries differ from the other peripheral countries of the European Union in terms of R&D expenditure in times of challenging economic circumstances.

Practical implications: The results call for a further strengthening of conditions to support R&D expenditure, firms' innovation attitudes and knowledge transfer, among others, between the research system, government institutions and firms in order to support firms' resilience to changes in economic environment.

Originality/value: The research contributes to the discussion on firms' innovation activities and their adaptation to challenging economic circumstances. In this context, the study focuses on R&D expenditure and provides evidence on how expenditure in question differ across the Visegrad Group countries in times of inflationary pressure and the covid pandemic.

Keywords: R&D expenditure, innovation activities of firms, the Visegrad Group countries, challenging economic environment, resilience.

Category of the paper: research paper.

1. Introduction

In recent years, there has been an increase in studies related to the resilience of firms, regions and countries to challenging economic environment (Teixeira et al., 2013; van der Loos et al., 2024) in response to the financial crisis, periods of inflationary pressure and the covid pandemic (Wziątek-Kubiak, Pęczkowski, 2021). This is related to the need to study the attitude and maintenance of firms, regions and countries towards change in order to maintain or improve competitiveness (Pacheco et al., 2023). In this area, particular research interest has been placed on the drivers and sources of resilience of firms, regions and countries (Gupta, 2020, Van der Loos et al., 2024). In this context, an important strand of the literature has paid particular attention to firms' innovation activities as crucial for the resilience of firms, regions and countries in challenging economic times (Viana et al., 2023). This is because firms' innovation performance plays an essential role in the development of not only firms, but also regions and countries, affecting their competitiveness (Audretsch, Belitski, 2024). For this reason, studies on resilience have drawn attention to the drivers and sources of firms' innovation activities as support for adaptation to severe conditions, such as, among others, economic crises (Bristow et al., 2018; Pinto et al., 2019). In this respect, particular emphasis has been paid to research and development (R&D) activities as crucial for firms' innovation performance and firms' resilience to challenging economic environment (Gupta, 2020; Wyrwa, 2022). Studies on resilience have considered here not only R&D activities of firms, but also those of the research system and the government institutions as essential for knowledge transfer and innovation processes (Wyrwa, 2022). This is consistent with endogenous growth, resilience and knowledge spillovers theories (Viana et al., 2023; Audretsch, Belitski, 2024). Among the studies on R&D activities, one strand of the research has focused on R&D expenditure as important for firms' innovation activities and the resilience of firms and, consequently, of regions and countries.

The growing importance of the issues related to resilience of firms, regions and countries, as well as the drivers of firms' innovation performance in challenging economic times, have stimulated this research. As few studies have focused on the area of R&D expenditure in relation to the Visegrad Group countries, this research addresses this gap.

Therefore, the aim of this study is to examine how R&D expenditure differs among the Visegrad Group countries in challenging economic environment. The research was based on data from Eurostat. The research period was 2011-2022, when the Visegrad Group countries faced inflationary pressure and the covid pandemic. The hypothesis was tested using the comparative analysis, zero unitarization method and the multivariate analysis.

This research offers a compliment to the existing research on resilience of firms to challenging economic times and the ongoing discussion on the drivers of firms' innovation activities. The study pays special attention to R&D expenditure and shows how expenditure in question differ across the Visegrad Group countries. This study also sheds further light on R&D expenditure in the face of challenging economic environment.

The remainder of the paper is as follows: the first section presents the theoretical background and the hypothesis. The next section describes the data and the methodology applied to identify how R&D expenditure differs among the Visegrad Group countries in challenging economic times. The results are then presented and discussed. In the last section, the conclusions are presented, including implications, limitations and suggestions for further research.

2. Literature review

The debate on the drivers and sources of resilience of firms, regions and countries is still ongoing, as there is a growing need to understand the issues related to adaptation to challenging economic times (Engelen et al., 2021; van der Loos et al., 2024). In recent years, explicit attention has been paid in this area to the drivers and sources of firms' innovation performance (Asheim, Herstad, 2021). The reason for this is that firms' innovation performance could support the resilience of firms as well as regions and countries (Gupta, 2020; Engelen et al., 2021). This is because there are strong theoretical reasons to believe that firms' innovation activities affect on the competitiveness of regions and countries (Audretsch, Belitski, 2024). This link is of interest to the theory of endogenous growth and knowledge diffusion, which emphasises networks between firms and, inter alia, the research system and the government institutions. Building on this, scholars have considered various drivers and sources of firms' innovation activities in relation to firms' resilience to challenging economic times (Pinto et al., 2019; Viana et al., 2023). In this respect, R&D activities have received particular attention in recent years (Teixeira et al., 2013; Gupta, 2020). The importance of these stems from the fact that R&D activities are seen as a stimulator of firms' attitude towards innovation (Wziątek-Kubiak, Pęczkowski, 2021).

Regarding R&D activities and resilience, the increasing importance of R&D expenditure is considered in the studies as crucial for firms' innovation activities and their adaptation to challenging economic times (Bristow, Healy, 2018; Gupta, 2020; Engelen et al., 2021; Viana, 2022). The analysis of the literature in this area highlights different approaches to consider R&D expenditure, given its multidimensional nature. In this context, Viana et al. (2022) point to the importance of expenditure on research and development (in general term) for innovation and resilience processes. Bristow and Healy (2018), Gupta (2020), Engelen et al. (2021)

consider R&D expenditure of firms as essential for firms' adaptation to challenging economic circumstances. Other studies also point to the importance of R&D expenditure of the government and the higher education sectors as substantial in supporting firms' innovation activities and knowledge transfer (Blanco et al., 2020; Maikel et al., 2020; Rehman et al., 2020). In this sense, Maikel et al. (2020), analysing 28 OECD countries over the period 1995-2017, provide evidence that R&D expenditure of the government sector supports firms' innovation activities and helps firms to be resilient to economic crises. On the other hand, Blanco et al. (2020) analyse the convergence of R&D expenditure in the European Union countries (taking into account the financial crisis of 2008) and show different attitudes of firms' R&D expenditure, R&D expenditure of the government sector and R&D expenditure of the higher education sectors towards the economic crisis. Similarly, Rehman et al. (2020) focus on R&D expenditure of firms, the research system and the government institutions in the European Union (considering the financial crisis of 2008) and provide evidence that research and development expenditure of the government and the higher education sectors encourage and support firms' innovation performance in the face of economic crises.

The rising relevance of R&D activities is also observed in the studies on the Visegrad Group countries, which also consider the issues related to R&D expenditure. However, the majority of them refer to R&D expenditure in the context of innovation performance of firms and do not address the occurrence of the challenging economic environment. In this respect, among others, Ivanová and Žárská (2023) analyse R&D expenditure in the context of the aggregate innovation index. Hunady et al. (2017) provide evidence on the relationship between gross domestic R&D expenditure and the development of regions from the Visegrad Group countries. Another study by Bednarzewska and Zniczuk (2024) examines the drivers of triple helix cooperation readiness in the Visegrad countries, with a special focus on R&D expenditure. On the other hand, Bočková (2013) analyses R&D expenditure by sector in the Visegrad Group countries in comparison with the other countries of the European Union, and shows that the Visegrad Group countries are characterized by a low level of R&D expenditure during the period 2006-2011. Jabłońska (2020) examines the regions of the Visegrad Group countries in the terms of R&D activities (including also R&D expenditure) and shows the increase of R&D activities after the accession to the European Union countries.

Over the last couple of years, studies on R&D activities and the resilience of firms in the Visegrad Group countries have also been noted. However, they are relatively scant. Among these studies, Bachmann and Frutos-Bencze (2022) emphasise that R&D activities of universities, including those from the Visegrad Group countries, support the resilience of firms during the covid pandemic (through knowledge transfer and strengthening firms' innovation activities). Dorożyński and Kuna-Marszałek (2016) consider R&D activities when investigating the attractiveness of innovation in the Visegrad Group countries during the financial crisis of 2008. The emphasis on R&D expenditure and resilience in challenging economic times can also be seen in the studies of Kotorov et al. (2023) and Wibisono (2023).

In this context, Kotorov et al. (2023) analyse R&D expenditure under the covid pandemic in, among others, two countries of the Visegrad Group – Czechia and Poland. This research provides evidence that the covid pandemic has no long-term effect on total R&D expenditure. Another study, by Wibisono (2023), focuses on R&D expenditure in regions of the Visegrad Group countries during the financial crisis of 2008. In this respect, the research shows that R&D expenditure strengthens the innovation potential and resilience of Czechia, Hungary and Poland.

The above studies indicate the importance of R&D expenditure in challenging economic circumstances and encourage for further research. While there are only few studies focusing on R&D expenditure in the Visegrad Group countries in challenging economic times, this study aims to fill this gap. Therefore, the hypothesis of this study is as follows:

H: R&D expenditure differs among the Visegrad Group countries in challenging economic environment.

3. Methodology

In order to understand how R&D expenditure differs among the Visegrad Group countries in challenging economic environment, Eurostat data was used as a database providing information on the Member States of the European Union. The study includes R&D expenditure by sector (in relation to gross domestic product) to capture the changes in expenditure on research and development activities in times of economic shocks. In this respect, the research focuses on sectors such as: the business enterprise sector, the government sector and the higher education sector as related to the triple helix, which is crucial for knowledge transfer and innovation activities of firms. The study contains also intramural R&D expenditure as essential for an analysis of all expenditure on research and development (current expenditure and gross fixed capital expenditure for R&D) in relation to total expenditure. In this respect, the intramural R&D expenditure of the business enterprise sector and of the government sector have been taken into considerations. To indicate the changes in R&D expenditure among the Visegrad Group countries in challenging economic circumstances, the research period was 2011-2022. The main statistics of the variables used in the study and their description can be found in Table 1.

Table 1.
Descriptive statistics

Variable	Description	Mean	St. Dev.	Min.	Max.
R&D expenditure of the business enterprise sector (X_1)	R&D expenditure of the business enterprise sector (as a percentage of gross domestic product)	0.77	0.28	0.41	1.07
R&D expenditure of the government sector (X_2)	R&D expenditure of the government sector (as a percentage of gross domestic product)	0.20	0.09	0.09	0.33
R&D expenditure of the higher education sector (X_3)	R&D expenditure of the higher education sector (as a percentage of gross domestic product)	0.31	0.10	0.20	0.44
Intramural R&D expenditure of the business enterprise sector (X_4)	Intramural R&D expenditure of the business enterprise sector (as a percentage of total)	43.44	6.02	35.07	50.89
Intramural R&D expenditure of the government sector (X_5)	Intramural R&D expenditure of the government sector (as a percentage of total)	37.29	3.91	32.78	42.61

Source: own study based on data from Eurostat, 2024.

The hypothesis was tested using the comparative analysis, zero unitarization method and the multivariate analysis. The use of the comparative analysis enables to analyse how R&D expenditure differs among the Visegrad Group countries in challenging economic circumstances. The application of zero unitarization method and the multivariate analysis allow to examine how the Visegrad Group countries differ in the field of R&D expenditure in challenging economic times. The usage of these methods is motivated by their applicability in studies of differences between regions and countries (Kiselakova et al., 2020; Zygmunt, 2024). In order to understand how the countries of the Visegrad Group differ in the field of R&D expenditure under the occurrence of economic conditions of high constraints four classes were identified to show: (i) the Visegrad countries with a very high level of R&D expenditure variables, (ii) the Visegrad countries with a high level of R&D expenditure variables, (iii) the Visegrad countries with an average level of R&D expenditure variables, (iv) the Visegrad countries with a low level of R&D expenditure variables. A constant reference point was used to normalise the variables in the first step (Kukuła, Bogocz, 2014):

$$R(X_{jt}) = \max_{it} x_{ijt} - \min_{it} x_{ijt} \quad (1)$$

As the variables used in the study are stimulants, they have been standardised by means of the following formula (Kukuła, Bogocz, 2014):

$$z_{ijt} = \frac{x_{ijt} - \min_{it} x_{ijt}}{\max_{it} x_{ijt} - \min_{it} x_{ijt}}, \quad (2)$$

where $z_{ijt} \in [0,1]$; ($i = 1,2, \dots, n$); ($j = 1,2, \dots, m$); ($t = 1,2, \dots, l$).

The synthetic index was then used (Kiselakova et al., 2020):

$$SM_{it} = \frac{1}{m} \sum_{j=1}^m z_{ijt}, \quad (3)$$

where $z_{ijt} \in [0,1]$; $SM_{it} \in [0,1]$; ($i = 1,2, \dots, n$); ($j = 1,2, \dots, m$); ($t = 1,2, \dots, l$).

The countries of the Visegrad Group were then divided according to the following formula:

1. The Visegrad countries with a very high level of R&D expenditure variables:

$$SM_{it} \geq \overline{SM}_{it} + S(SM_{it}), \quad (4)$$

where $(i = 1, 2, \dots, n); (t = 1, 2, \dots, l)$.

2. The Visegrad countries with a high level of R&D expenditure variables:

$$\overline{SM}_{it} \leq SM_{it} < \overline{SM}_{it} + S(SM_{it}), \quad (5)$$

where $(i = 1, 2, \dots, n); (t = 1, 2, \dots, l)$.

3. The Visegrad countries with an average level of R&D expenditure variables:

$$\overline{SM}_{it} - S(SM_{it}) \leq SM_{it} < \overline{SM}_{it}, \quad (6)$$

where $(i = 1, 2, \dots, n); (t = 1, 2, \dots, l)$.

4. The Visegrad countries with a low level of R&D expenditure variables:

$$SM_{it} < \overline{SM}_{it} - S(SM_{it}), \quad (7)$$

where:

$(i = 1, 2, \dots, n); (t = 1, 2, \dots, l)$.

Where (Zygmunt, 2024):

$$\overline{SM}_{it} = \frac{1}{n} \sum_{j=1}^n SM_{it}, \quad (8)$$

where $(i = 1, 2, \dots, n); (t = 1, 2, \dots, l)$.

$$S(SM_{it}) = \sqrt{\frac{1}{n} \sum_{i=1}^n (SM_{it} - \overline{SM}_{it})^2}, \quad (9)$$

where $(i = 1, 2, \dots, n); (t = 1, 2, \dots, l)$

This procedure enables an analysis of how the countries of the Visegrad Group differ in terms of R&D expenditure in challenging economic environment.

4. Results and discussion

The results of the comparative analysis of the R&D expenditure variables for the Visegrad Group countries in challenging economic environment provide some interesting insights (Figures 1-5). Considering R&D expenditure by sector (Figures 1-3), the results show that the business enterprise sector stands out in terms of expenditure on research and development as the percentage of gross domestic product. This feature suggests that, despite the occurrence of conditions of high economic constraints faced by firms from the Visegrad Group countries between 2011 and 2022, a focus on improving innovation performance is evident. This may lead to an improvement in firms' competitiveness and strengthen firms' resilience to challenging economic times. This is in line with the study of Viana et al. (2023), which indicates that innovation activities of firms can be seen as increasing the ability of firms to adapt to changes in the economic environment.

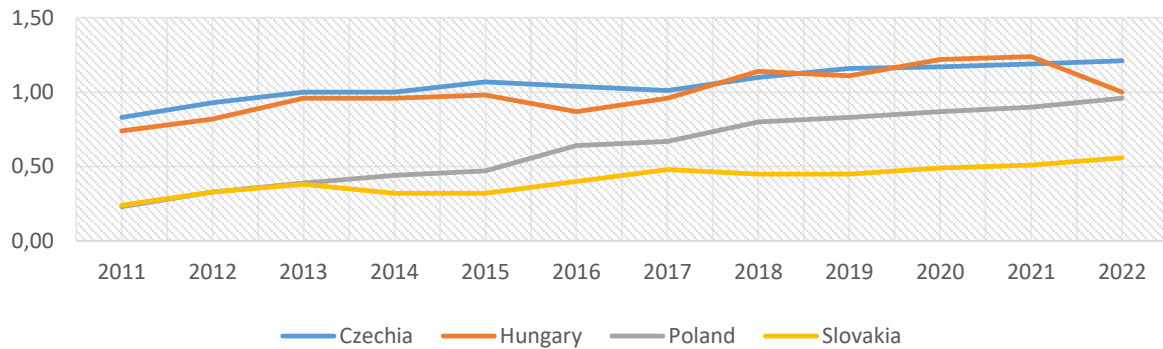


Figure 1. R&D expenditure of the business enterprise sector in the Visegrad Group countries in 2011-2022 (% of gross domestic product).

Source: own study based on data from Eurostat, 2024.

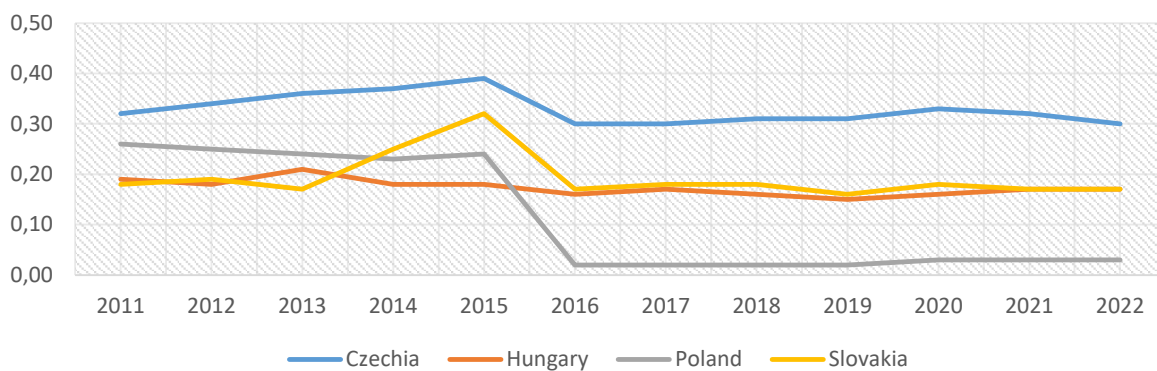


Figure 2. R&D expenditure of the government sector in the Visegrad Group countries in 2011-2022 (% of gross domestic product).

Source: own study based on data from Eurostat, 2024.

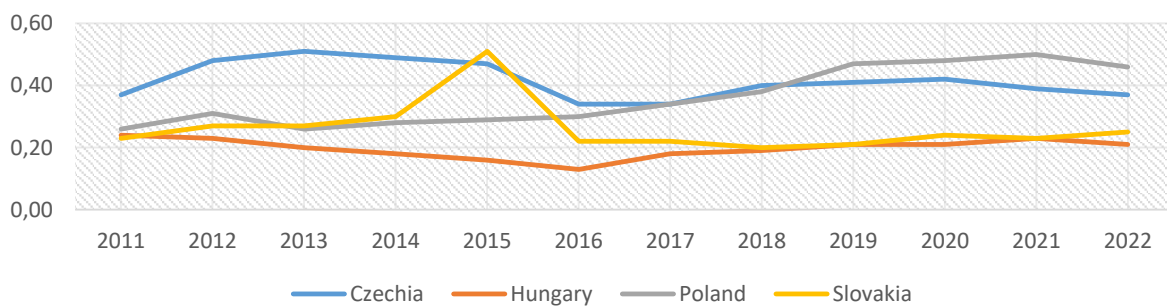


Figure 3. R&D expenditure of the higher education sector in the Visegrad Group countries in 2011-2022 (% of gross domestic product).

Source: own study based on data from Eurostat, 2024.

The results also reveal an upward tendency in R&D expenditure of firms from the Visegrad Group countries in the period 2011-2022, when firms are recovering from the financial crisis of 2008, and facing inflationary pressure and the covid pandemic. It shows that firms from the Visegrad Group countries tend to improve their ability to be innovate in challenging economic environment in order to be more competitive. Such a characteristic should be seen as positive and is consistent with the study by Wibisono (2023). According to the results, firms from

Czechia and Hungary were characterized by the highest level of R&D expenditure. This may be an indication of their higher potential for improving innovation activities of firms, their competitiveness and, consequently, the competitiveness of regions and countries.

Regarding the level of R&D expenditure of the government and the higher education sectors in the Visegrad Group countries, the results imply their increase until 2015. This may indicate the attitude of these sectors to become more competitive in order to support the development and resilience of regions and countries. This is in line with the study by Blanco et al. (2020) and Maikel et al. (2020). The significant decrease in research and development expenditure (as the percentage of gross domestic product) in these sectors is noticeable in 2016, which may be linked to the end of the programmes to support innovation in the European Union's 2007-2013 programming period. The results imply that since 2017 the level of R&D expenditure of the higher education sector is relatively increasing, which may indicate an ongoing need to strengthen the innovation potential of the research system. Significantly, this feature has been seen during the occurrences of inflationary pressure and the covid pandemic faced Visegrad Group countries during the analysed period. This should be treated as positive, as the research system is considered important for knowledge transfer to support firms' innovation activities. This is consistent with the study by Rehman et al. (2020), which suggests that the research system is crucial for the resilience of firms to challenging economic circumstances. Among the Visegrad Group countries, Czechia and Hungary have the relatively highest expenditure on R&D in the higher education sector, indicating relatively high potential for knowledge transfer. The results also imply that from 2016, the R&D expenditure of the government sector stands on the stable level despite challenging economic times. This may indicate that the government institutions are aware of the need to create conditions that support firms' ability to innovate. This is in line with the study provided by Maikel et al. (2020). The results show that among the Visegrad Group countries, Poland is characterized by the lowest level of expenditure on research and development in the period 2016-2022. This may lead to a potential deterioration in the government institutions to stimulate firms' innovativeness and their competitiveness, especially in the face of the need adapt to changes in the economic environment.

Regarding the intramural R&D expenditure of the business enterprise and the government sectors the results also imply important features (Figures 4-5).

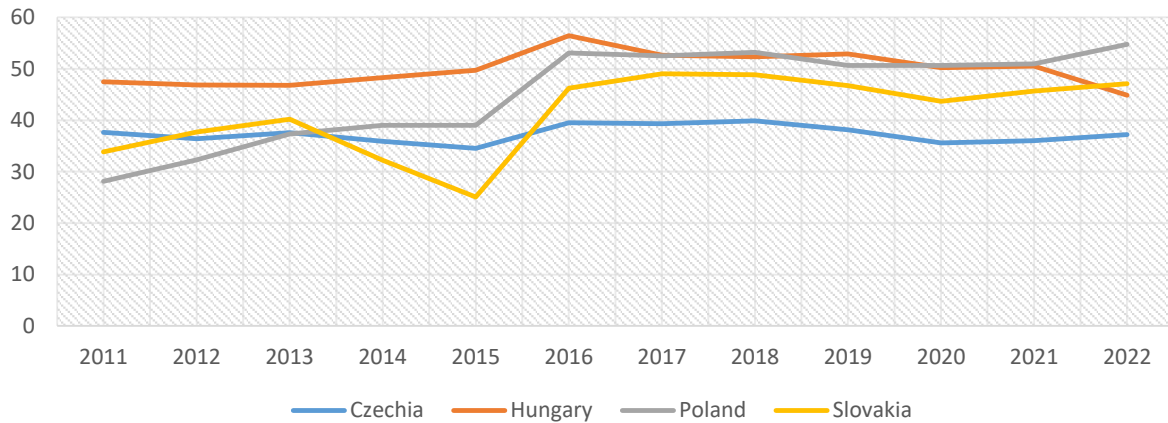


Figure 4. Intramural R&D expenditure of the business enterprise sector (% of total).

Source: own study based on data from Eurostat, 2024.

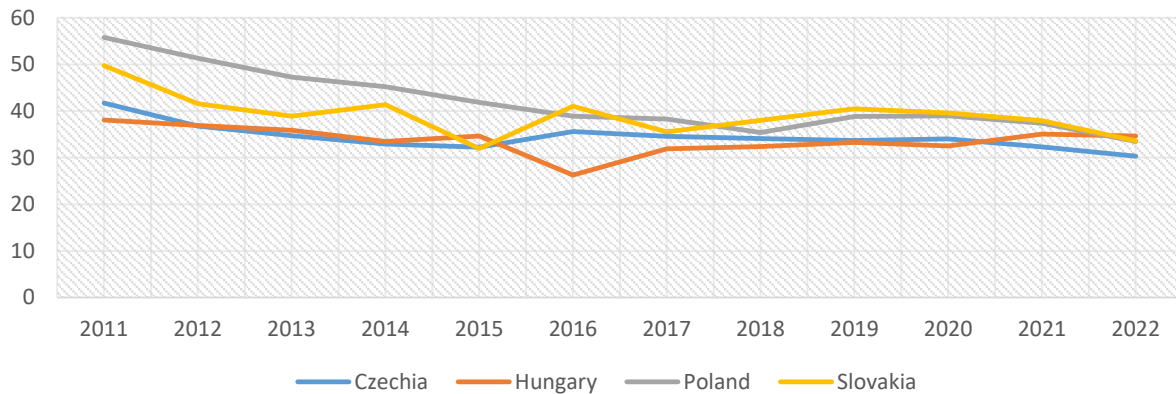


Figure 5. Intramural R&D expenditure of the government sector (% of total).

Source: own study based on data from Eurostat, 2024.

According to the results, the intramural R&D expenditure of the business enterprise sector in the Visegrad Group countries is characterized by a relative increase over the period analysed. This is particularly evident since 2016, when the share of intramural expenditure on research and development increased in all the Visegrad Group countries. The results suggest that this level of intramural expenditure on R&D has been maintained even during the occurrences of inflationary pressure and the covid pandemic, which Visegrad Group countries faced in the analysed period. This may indicate that firms from the Visegrad Group countries tend to strengthen their innovation activities in order to be more resilient to economic shocks associated with difficult conditions. This is consistent with the findings of Bachmann and Frutos-Bencze (2022). The results show that among the Visegrad Group countries, Hungary and Poland stand out in terms of the intramural R&D expenditure by the business enterprise sector. Czechia, on the other hand, is characterized by the lowest level of such expenditure, which may limit the ability of Czech firms to react quickly to different economic times.

The results also allow to observe the decreasing level of all expenditure on research and development (current expenditure and gross fixed capital expenditure on R&D) in relation to total expenditure in the government sector between 2011 and 2022. This feature is evident for

all the Visegrad Group countries and may lead to a reduced capacity to stimulate firms' innovation activities, especially when firms face challenging economic circumstances and need support. This may affect not only the competitiveness of firms, but also the competitiveness of regions and countries.

Considering the results of zero unitarization method and the multivariate analysis the findings provide evidence of the relatively high diversity among the Visegrad Group countries in terms of expenditure on R&D in the period 2011-2022 (Tables 2-4). This is in line with the stated hypothesis and offers some interesting insights.

Table 2.

Results of the multivariate analysis of R&D expenditure in the Visegrad Countries – part 1

2011			2012			2013			2014		
No.	Co.	SM	No.	Co.	SM	No.	Co.	SM	No.	Co.	SM
Very High			Very High			Very High			Very High		
1.	Czechia	0.740	1.	Czechia	0.656	1.	Czechia	0.606	1.	Czechia	0.646
Average			Average			High			Average		
1.	Hungary	0.398	1.	Hungary	0.364	1.	Hungary	0.447	1.	Poland	0.437
						Average					
2.	Poland	0.357	2.	Poland	0.352	1.	Poland	0.316	2.	Hungary	0.397
Low			Low			Low			Low		
1.	Slovakia	0.194	1.	Slovakia	0.184	1.	Slovakia	0.172	1.	Slovakia	0.289

Source: own study based on data from Eurostat, 2024.

Table 3.

Results of the multivariate analysis of R&D expenditure in the Visegrad Countries – part 2

2015			2016			2017			2018		
No.	Co.	SM	No.	Co.	SM	No.	Co.	SM	No.	Co.	SM
Very High			Very High			Very High			Very High		
1.	Czechia	0.659	1.	Czechia	0.727	1.	Czechia	0.683	1.	Czechia	0.650
High			High			High			High		
1.	Poland	0.484	1.	Poland	0.568	1.	Poland	0.670	1.	Poland	0.591
Average			Average			Average			Average		
1.	Hungary	0.430	1.	Slovakia	0.472	1.	Hungary	0.488	1.	Hungary	0.484
Low			Low			Low			Low		
1.	Slovakia	0.333	1.	Hungary	0.447	1.	Slovakia	0.423	1.	Slovakia	0.454

Source: own study based on data from Eurostat, 2024.

Table 4.

Results of the multivariate analysis of R&D expenditure in the Visegrad Countries – part 3

2019			2020			2021			2022		
No.	Co.	SM	No.	Co.	SM	No.	Co.	SM	No.	Co.	SM
Very High			Very High			Very High			Very High		
1.	Czechia	0.565	1.	Poland	0.686	1.	Poland	0.688	1.	Poland	0.670
2.	Poland	0.631	High			High			Average		
Average			1.	Czechia	0.585	1.	Hungary	0.590	1.	Czechia	0.528
			Average			Average					
1.	Hungary	0.475	1.	Hungary	0.481	1.	Czechia	0.505	2.	Hungary	0.526
Low			Low			Low			Low		
1.	Slovakia	0.413	1.	Slovakia	0.430	1.	Slovakia	0.426	1.	Slovakia	0.401

Source: own study based on data from Eurostat, 2024.

The results reveal, among others, that the diversity between the Visegrad Group countries in terms of R&D expenditure have changed over the period under consideration. This may be a consequence of the attitude and ability of firms, the research system and the government institutions to be innovative and competitive in the face of difficult conditions. According to the results, the highest diversity among the Visegrad Group countries can be observed between Czechia and Slovakia (in the almost the whole period 2011-2019) and between Poland and Slovakia (between 2020-2022). In this respect, Czechia (2011-2019) and Poland (2020-2022) have the very high levels of the R&D expenditure variables used in the study, compared to the other Visegrad Group countries. This implies that these countries, despite the occurrence of inflationary pressure and the covid pandemic, have the highest ability to strengthen firms' innovation activities through research and development expenditure. This may provide a greater ability to strengthen their resilience and competitiveness and, consequently, the resilience and competitiveness of regions and countries. This is in line with the study by Wibisono (2023). On the other hand, Slovakia, compared to the other the Visegrad Group, is characterized by the lowest level of the variables related to the R&R expenditure. This is observed throughout the period analysed suggesting that Slovakia may have a limited ability to react and adapt to changes in the economic environment. Such an occurrence may have an impact on the ability of Slovak firms to innovate. The results also show that the average level of the variables related to expenditure on research and development in Hungary is almost unchanged for throughout the period 2011-2022. This suggests that despite the challenging economic circumstances, Hungary maintained the average level of R&D expenditure. This suggests the potential of Hungarian firms, the research system and the government sector to maintain the resilience in challenging economic times.

5. Conclusions

This study adds to the discussion on firms' innovation activities and their resilience to challenging economic circumstances. In this respect, the article focuses on R&D expenditure and provides evidence on how expenditure in question differ across the Visegrad Group countries. The period 2011-2022, when the Visegrad countries faced inflationary pressure and the covid pandemic, was of particular interest. The results indicate the relatively high diversity among the Visegrad Group countries in terms of R&D expenditure. This may have consequences for firms' innovation performance and their adaptation to challenging economic times. The research shows that Czechia and Poland distinguish the very high level of R&D expenditure variables, which may indicate a high ability to strengthen innovation activities of firms despite challenging economic circumstances. The results also provide evidence that

Slovakia is characterized by the relatively low level of R&D expenditure variables. This may have implications for the resilience of Slovak firms to changes in the economic environment.

The study has implications for policy makers and practitioners. Regarding the importance of R&D expenditure for firms' innovation activities and their resilience to challenging economic environment, it seems important for policy makers to further strengthen the conditions to support firms' innovation attitudes as well as knowledge transfer between the research system (as a knowledge provider for innovation) and firms. On the other hand, firms should take actions to further strengthen their innovation performance to support resilience to challenging economic times.

There are limitations to this study that could be areas for future research. In particular, since this study focuses on R&D expenditure by sector (in relation to gross domestic product) and intramural R&D expenditure of the business enterprise sector and of the government sector (in relation to total expenditure) it would be beneficial to use other variables describing R&D expenditure and to examine whether the results obtained also hold for them. The other area of research that needs further attention is to examine the reasons for the observed discrepancies among the Visegrad Group countries in terms of R&D expenditure in challenging economic circumstances. Furthermore, as the study focuses on the Visegrad Group countries, a fruitful area of research would be to investigate how the Visegrad Group countries differ from the other peripheral countries of the European Union in terms of R&D expenditure in challenging economic environment.

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