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KNOWLEDGE TRANSFER AS A FEATURE OF SMALL AND MEDIUM-SIZED ENTERPRISES' RESILIENCE TO CHALLENGING ECONOMIC CONDITIONS: EVIDENCE FROM PERIPHERAL COUNTRIES

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ABSTRACT: The aim of this paper is to examine whether and how peripheral countries differ in terms of knowledge transfer as a feature of small and medium-sized enterprises (SMEs) resilience to challenging economic conditions (economic shocks). The study focuses on the Visegrad Group countries, which are peripheral within the European Union, offering a unique research context due to their similar cultural backgrounds and transition from centrally planned to market economies. The research covers the period 2016–2023, a period characterised by inflationary pressures and the COVID-19 pandemic. The study uses a comparative analysis and zero unitarization method to test the hypothesis. The results demonstrate that while there were significant differences in the level of knowledge transfer in the peripheral countries studied, all Visegrad Group countries showed a consistent upward tendency in knowledge transfer over the analysis period. The study contributes to the growing body of research on firms' resilience by suggesting that knowledge transfer in the periphery serves as a mechanism to increase SMEs' resilience to market or environmental disturbances and, more broadly, to the sustainable development of countries.

KEYWORDS: knowledge transfer, challenging economic conditions, peripheral countries, the Visegrad Group, resilience, sustainable development

Introduction

Sustainable development understood as a process that balances economic growth, social equity and environmental protection (Du Pisani, 2006) is widely recognised as a framework for addressing the unique challenges faced by regions and countries, with a focus on long-term growth and prosperity (Warchold et al., 2020). However, for peripheral regions and countries, implementing sustainable development entails significant challenges due to limited resources (Grillitsch & Nilsson, 2015) and increased vulnerability to global and local shocks (van Aswegen & Retief, 2020). This highlights the importance of resilience, which is the ability to withstand market or environmental disruptions without diminishing the ability to allocate resources efficiently or provide core services (Martin & Sunley, 2015). Resilience not only enables a region to bounce back from challenging economic conditions, but can also facilitate the process of following sustainable development pathways (Smit & Wandel, 2006). Its critical importance is underlined by European Union actions, such as the establishment of the Recovery and Resilience Facility in 2021 to address the economic and social impact of the pandemic on its member states, with €650 billion allocated for this purpose (European Commission, 2024a).

The extent to which a region is resilient influences the firms that operate there and their own resilience. This relationship is interdependent, as the resilience of firms can contribute to regional stability by maintaining employment, fostering innovation, and increasing economic diversification (Tsiapa & Batsiolas, 2018). In this context, firms' resilience emerges as a key driver of regional recovery and long-term sustainability. As the increasing relevance of firms' resilience to challenging economic conditions becomes more apparent to both scholars and practitioners (Kononiuk & Magruk, 2024), there is a growing need for further research to explore this important area. In particular, Bristow and Healy (2018) highlight the role of innovation and emphasise that more in-depth empirical investigation of the relationship between resilience and innovation is needed, as the latter has been identified as a crucial element in the long-term renewal of regional development pathways (Filippetti et al., 2020). Moreover, to date, relatively few studies have focused on knowledge transfer in the peripheral countries, with its importance for resilience remaining largely underexplored.

The purpose of this study is therefore to fill this gap by focusing on small and medium-sized enterprises (SMEs), which represent 99% of enterprises in the European Union (European Commission, 2024b) and whose survival and growth are considered particularly vulnerable to the interplay between their resilience and their capacity to innovate (Pilav–Velic et al., 2024). This study focuses on the Visegrad Group countries, which are peripheral within the European Union and provide a unique research context. They underwent the transition from centrally planned to market economies during the same period (Zygmunt, 2018) and share a similar cultural background. However, despite these similarities, it can be argued that the role of knowledge transfer in enhancing the resilience of firms to challenging economic conditions may vary significantly due to social, behavioural, institutional and political factors that peripheral, transition countries may address in different ways. Investigating this is particularly important given the ongoing economic transformations in these countries, where innovation plays a crucial role in sustainable development (Kobylińska & Irimia-Dieguez, 2023).

The aim of this study is therefore to examine whether and how the peripheral countries differ in terms of knowledge transfer as a feature of SMEs' resilience to challenging economic conditions. In order to reach the aim of the study, the comparative analysis and zero unitarization method were used. The study is based on data from the European Innovation Scoreboard 2023 (EIS) (European Commission, 2024c) and covers the period from 2016 to 2023, a time during which SMEs in the countries under study faced inflationary pressures and the challenges posed by the covid pandemic.

This study contributes to the literature on SMEs resilience and sustainable regional development by focusing on knowledge transfer as a means for SMEs to withstand economic shocks. It also adds to the growing body of research on resilience in peripheral countries by providing new insights into the different levels of knowledge transfer during challenging economic conditions among peripheral countries with similar cultural and transition contexts. The study also advances the conceptualisation and measurement of knowledge transfer, by using a synthetic index to capture its level during challenging economic conditions. For policy makers, the study provides recommendations on strengthening conditions that support knowledge collaboration in order to enhance SMEs resilience and promote sustainable development.

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The article proceeds as follows: first, the theoretical foundation is presented. This is followed by a description of the research methodology. The results of the empirical research are then presented and discussed, together with the limitations of the study and suggestions for future research. Finally, conclusions are drawn, highlighting both scientific and practical implications.

An overview of the literature

Small and medium-sized enterprises are recognised as being crucial to the economic growth (Floyd & McManus, 2005), stimulating job creation and competitiveness of regions and countries. However, they often lack resilience and have been proven to be highly vulnerable to a wide range of external shocks (Branicki et al., 2018), such as financial crises, pandemics, severe weather events. The way in which SMEs can cope with the challenging economic conditions that such shocks tend to create is through their ability to innovate (Dovbischuk, 2022). Indeed, from the perspective of endogenous growth theory, firms that innovate are more likely to achieve growth and long-term survival (Grossman & Helpman, 1994), even in the face of economic shocks. Innovative firms have been found to have a higher levels of acquired or potential knowledge about the challenging economic conditions (Bristow & Healy, 2018), and tend to outperform other firms (Sorescu & Spanjol, 2008). Innovation performance has been proven to enhance firm resilience, particularly when exploitative innovation is involved (Pilav-Velic et al., 2024), with firms that focus on improving their innovation capabilities more effectively leveraging the lessons learned from crises to support long-term survival (Kyrdoda et al., 2023). Previous studies have shown that, when research and development (R&D) intensity and patents are taken into account, innovation increases the stability and flexibility of firms during shocks, depending on the firm's profitability prior to the shock (Engelen et al., 2024).

Research indicates that innovation performance can be enhanced by seeking and acquiring external knowledge (Wang & Noe, 2010). This emphasis the important role of knowledge transfer, defined as the process of sharing and applying knowledge internally and externally (Darr & Kurtzberg, 2000), in building and enhancing firm resilience. Previous studies have explored the role of networks and tie strength in knowledge transfer, indicating that strong ties, such as those with family members and colleagues, are more likely to facilitate access to tacit knowledge, thereby enhancing a firm's knowledge creation capabilities (Filieri & Alguezaui, 2014). Particular attention has also been given to the role of trust and cultural values between the headquarters and the subsidiary (Asrar-ul-Haq & Anwar, 2016), which significantly influence the knowledge sharing and transfer process, as well as the motivations of individuals and firms for knowledge transfer (Darr & Kurtzberg, 2000). Previous studies have also focused extensively on knowledge spillovers, demonstrating the crucial role of external knowledge flows in fostering innovation. They have emphasised the importance of knowledge collaboration with external partners, including firms within and outside the sector, suppliers, customers, competitors, consultants, universities, R&D laboratories, and government agencies (Audretsch et al., 2023), for firm's innovation and performance. It is argued that firms that engage in such collaborations can gain access to a wider range of ideas and capabilities, which enables them to innovate more quickly and efficiently (Chesbrough, 2003).

While the influence of knowledge transfer on firm performance is well documented, its role in enhancing firm resilience has only recently begun to attract significant attention, driven by the increasing frequency of economic shocks globally. Despite this growing focus, research on how knowledge transfer contributes to firm resilience is still emerging. In challenging economic conditions, knowledge transfer can mitigate negative impacts by providing firms with access to alternative solutions and technologies, thereby enhancing not only the resilience of individual firms but also overall economic stability (van Aswegen & Retief, 2020). Torres et al. (2018) emphasise that a firm's capacity to establish and strategically leverage networks is a key factor in its ability to navigate disruptions and challenges. Among these, Kobylińska and Irimia-Dieguez (2023) highlight the central role of university collaboration, which can take several forms, including consulting and training, scientific and information exchange, and research and commercialisation. SMEs that engage in knowledge transfer with universities have been found to significantly outperform their peers during economic recessions (Añón Higón & Vicente-Chirivella, 2024). This suggests that during economic shocks, knowledge transfer not only drives innovation but also enables firms to remain adaptable and responsive.

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The existing literature on knowledge transfer has largely focused on developed regions and countries, leaving a gap in understanding how this process unfolds in the periphery. While the ability to withstand market or environmental disruptions is essential for firms in both central and peripheral regions, they face different challenges in coping with economic shocks. As noted by Grillitsch and Nilsson (2015), firms in peripheral regions benefit much less from local knowledge spillovers than firms located in agglomerations or industrial clusters. This can be attributed to a number of factors, including limited human capital, a narrower range of activities, weaker knowledge infrastructures, and fewer connections to leading knowledge centres (Pinheiro et al., 2022). As a result, regions and countries with limited knowledge transfer may find it more difficult to facilitate business adaptation and long-term growth in difficult economic conditions, which could consequently affect sustainable development. Indeed, regions with technologically coherent capabilities have been observed to adapt more effectively to economic shocks, with resilience being driven by their ability to generate new growth pathways (Rocchetta et al., 2022). It can be argued that in challenging economic conditions, firms in peripheral regions may seek to adopt resilience practices used by their counterparts in more developed areas. However, limited resources often constrain these efforts, forcing firms to innovate and develop new approaches to managing economic shocks. Furthermore, the varying levels of resources in peripheral regions are likely to lead to different approaches to enhancing the resilience of firms. This may also affect how knowledge transfer is leveraged in the process of resiliency building and enhancing. Exploring this issue is crucial, as it can lead to the development of tailored strategies and concepts for building and enhancing the resilience of firms in peripheral regions, both at the level of the individual firm and in the wider regional and national context. The Visegrad Group countries offer an excellent context for research on this topic, as they are considered peripheral, are located close to each other in Central and Eastern Europe, share a similar cultural backgrounds and have all undergone the transition from centrally planned to market economies at the same time. Therefore, the following hypothesis was established:

H: Knowledge transfer as a feature of SMEs resilience to challenging economic conditions differs among the Visegrad Group countries.

Research methodology

The study is based on data from the European Innovation Scoreboard 2023 as a dataset containing information on innovation performance of the member states of the European Union. To test the hypothesis, the data from the following dimensions of the EIS were used: attractive research system, linkages, innovators.

The attractive research system dimension asses competitiveness of a country's research system, which in turn helps to frame the innovation system in which SMEs operate. It includes the following variables: international scientific co-publications, top-10% most cited publications, foreign doctorate students. Focusing on the attractiveness of the research system is important for understanding its competitiveness. It plays a crucial role in knowledge transfer, which is vital for firms' innovation activities, especially in difficult economic conditions (Pinto & Guerreiro, 2019). International scientific co-publications serve as a measure of the quality of scientific collaboration. Such collaboration is an important source of knowledge, which is particularly valuable in challenging economic conditions (Lee & Haupt, 2021). The next variable, top-10% most cited publications, was included in the study as it provides information on highly-cited scientific publications, which are considered to be of higher quality. Such publications can facilitate knowledge transfer and enable a quicker response to change (Liu et al., 2023). In order to capture the role of the mobility of foreign doctorate students in knowledge transfer (Başak & Faist, 2015), the next variable, foreign doctorate students, was also applied.

The next dimension of the EIS from which data were drawn in this study, relates to the the linkages. This dimension provides data on knowledge transfer between firms and other firms and between firms and the research system and is expressed by the following variables: innovative SMEs collaborating with others and public-private co-publications. As external collaboration enhances the adaptability of firms to changes in the economic conditions (Boschma, 2015), it is essential to consider these variables in the study. The first of these, innovative SMEs collaborating with others, measures the involvement of SMEs in collaborating with external knowledge providers, such as other

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firms or institutions, in order to strengthen innovation activities and competitiveness (Audretsch et al., 2023). The next variable, public-private co-publications, measures active scientific collaboration between firms and other actors in the research system, in particular universities. Such collaborations are vulnerable to challenging economic conditions, during which firms become more aware of the competitive advantages that can be gained from such partnerships (Azagra-Caro et al., 2018), thereby supporting firm resilience.

The innovators dimension provides data on the innovation activities of SMEs. It includes the following variables: SMEs with product innovation and SMEs with business process innovation. The innovation activities of firms are crucial for enhancing their resilience in the face of challenging economic conditions (Audretsch et al., 2023), with SMEs representing 99% of firms in the European Union (European Commission, 2024b). Accordingly, these variables were included in this study.

The study covers the period 2016–2023 and focuses on the Visegrad Group countries in challenging economic conditions, such as inflationary pressures and the covid pandemic. Table 1 provides definitions of the variables and summary statistics.

Table 1. Variables definitions and summary statistics

Variable	Description	Mean	St. Dev.	Min.	Max.
Innovative SMEs collaborating with others (X_1)	Innovative SMEs collaborating with others (as a percentage of SMEs)	7.93	2.76	4.34	11.66
Public-private co-publications (X_2)	Number of public-private co-publications per million population	113.60	36.54	62.75	161.38
International scientific co-publications (X_3)	Number of international scientific co-publications per million population	726.68	240.09	448.63	1102.91
Top-10% most cited publications (X_4)	Number of the top-10% most cited publications (as a percentage of total scientific publications of the country)	4.63	0.61	3.73	5.34
Foreign doctorate students (X_5)	Number of doctorate students from foreign countries (as a percentages of all doctorate students)	11.02	5.75	2.81	17.81
SMEs with product innovation (X_6)	SMEs introducing product innovation (as a percentage of SMEs)	15.78	5.95	10.13	25.49
SMEs with business process innovation (X_7)	SMEs introducing business process innovation (as a percentage of SMEs)	23.17	7.45	16.80	35.15

Source: authors' work based on European Commission (2024c).

In order to test the hypothesis, the comparative analysis and taxonomic method were used. The application of these methods in this study is justified by their usefulness in previous research on the comparison of objects and phenomena and the analysis of differences between regions and countries. For example, Zygmunt (2017) uses such a research approach to compare innovation activities of Polish firms with those of other moderate innovator countries. On the other hand, Malinowski and Jaworska (2018) and Kiselakova et al. (2020) apply this approach to assess the level of sustainable development in European Union member states. However, although this research approach is commonly used to examine the level of innovation and sustainable development of European Union countries, its application to the study of knowledge transfer and SMEs' resilience to challenging economic conditions is original. More specifically, the use of the comparative analysis in this study enables to gain an insight into the competitiveness of the research system in certain Visegrad Group countries and how knowledge transfer between firms and other firms and between firms and the research system has changed over the period considered. Taxonomic method, which in this study is the zero unitarization method, was applied to explore whether and how the Visegrad Group countries differ in terms of knowledge transfer as a feature of SMEs resilience to challenging economic conditions. In this respect, data were drawn from the following dimensions of the EIS: attractive research system and linkages. It was first used to construct a synthetic index representing knowledge transfer and

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then to assess in which Visegrad Group countries this transfer was (i) very high, (ii) high, (iii) average, or (iv) low. To achieve this, the variables were normalised using a constant reference point (Kukuła & Bogocz, 2014):

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

As the variables used in the research are stimulants, they have been standardised according to the formula (Kukuła & Bogocz, 2014):

$$z_{ijt} = \frac{x_{ijt} - \min_{it} x_{ijt}}{\max_{it} x_{ijt} - \min_{it} x_{ijt}} \,, \tag{2}$$

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 applied (Kiselakova et al., 2020):

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

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

Next, the Visegrad Group countries were classified using the formula:

(i) the Visegrad Group countries with a very high level of knowledge transfer:

$$SM_{it} \geq \overline{SM_{it}} + S(SM_{it}) \,, \tag{4}$$

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

(ii) the Visegrad Group countries with a high level of knowledge transfer:

$$\overline{SM_{it}} \leq SM_{it} < \overline{SM_{it}} + S(SM_{it}) \,, \tag{5}$$

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

(iii) the Visegrad Group countries with an average level of knowledge transfer:

$$\overline{SM_{it}} - S(SM_{it}) \leq SM_{it} < \overline{SM_{it}} \,, \tag{6}$$

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

(iv) the Visegrad Group countries with a low level of knowledge transfer:

$$SM_{it} < \overline{SM_{it}} - S(SM_{it}) \,, \tag{7}$$

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

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where:

$$\overline{SM_{it}} = \frac{1}{n}\sum_{i=1}^{n} SM_{it} \quad , \tag{8}$$

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

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

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

Next, a regression analysis was used to analyse the relationships between the variables and their impact on the level of knowledge transfer in the Visegrad Group countries during the period under consideration. The model is expressed as:

$$SM_{it} = X_{1it}\beta_1 + X_{2it}\beta_2 + X_{3it}\beta_3 + X_{4it}\beta_4 + X_{5it}\beta_5 + \alpha_i + \varepsilon_{it} \quad , \tag{10}$$

Given the length of the time period and the number of independent variables, stepwise regression was used. This approach allowed the identification of the most influential variables while reducing the risk of developing a biased model that could lead to incorrect conclusions about the significance of the predictors. Forward stepwise regression was performed by beginning with an empty model and at each step adding the variable that improved its fit until no additional variables could significantly improve it.

Figure 1 provides a summary of the research methodology. It shows the methods used and how they were applied in the study.

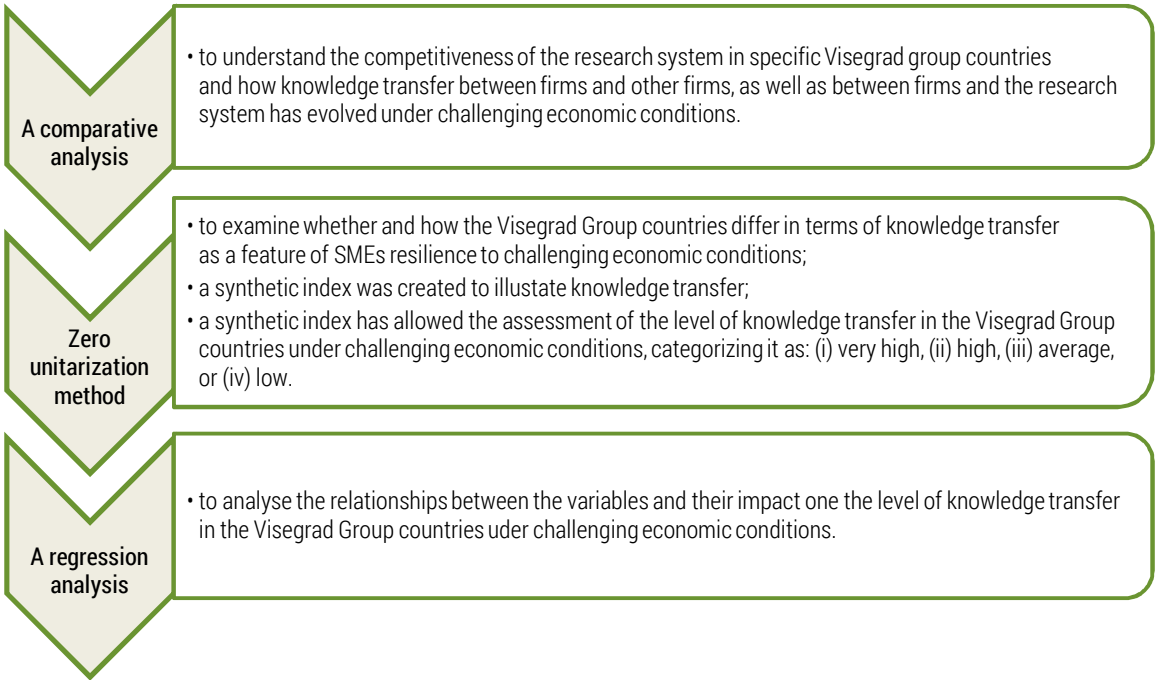

Figure 1. A summary of the research methodology

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Results of the research

Regarding the changes in the variables considered in this study that express knowledge transfer in the Visegrad Group countries over the period 2016–2023, the comparative analysis reveals a number of key findings (Figures 2–8). In this respect, the study provides evidence that that Czechia performs better than the other Visegrad Group countries both in terms of knowledge transfer between firms and other firms and between firms and the research system (Figures 2–3). This may lead to the highest potential of Czech SMEs to be more resilient to challenging economic conditions than the other the Visegrad Group countries.

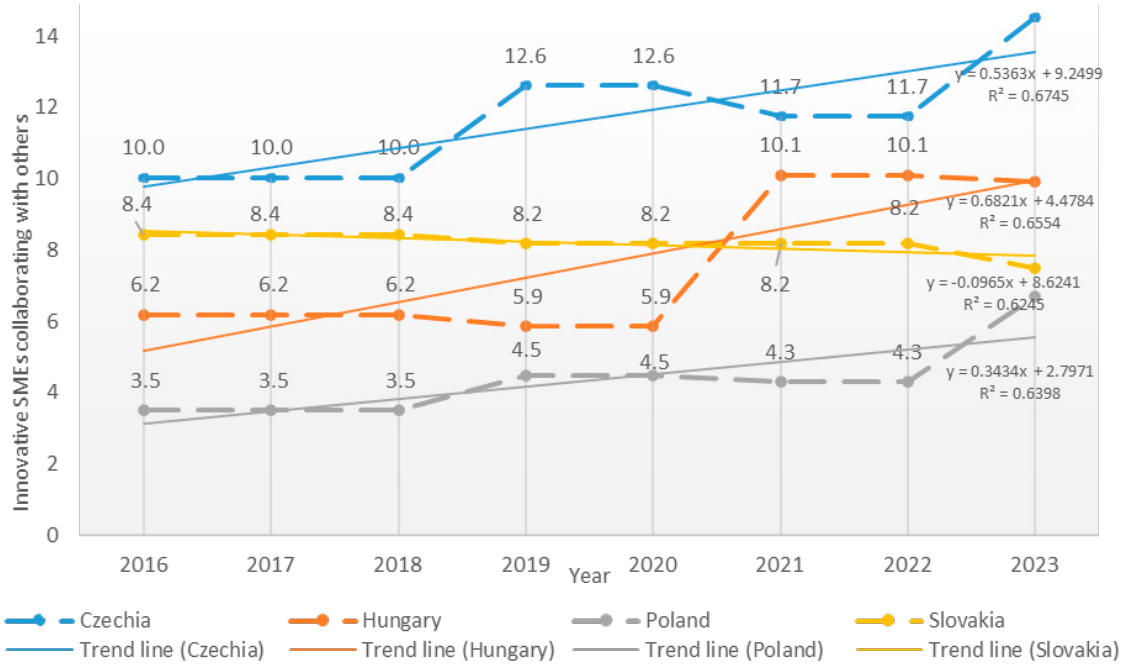

Figure 2. Innovative SMEs collaborating with others (a percentage of SMEs)

Source: authors' work based on European Commission (2024c).

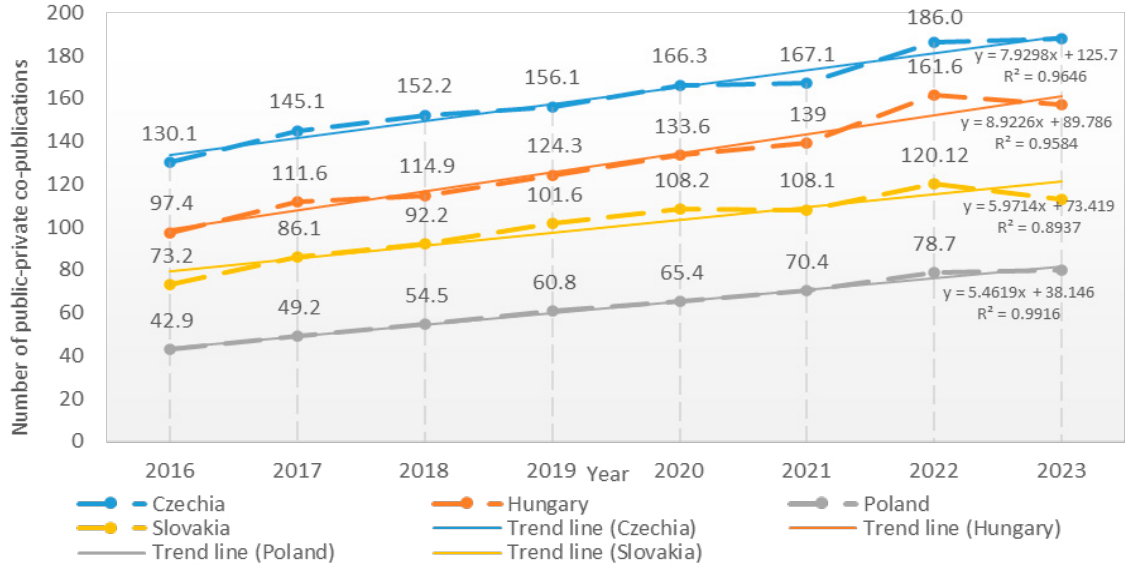

Figure 3. Number of public-private co-publications per million population

Source: authors' work based on on European Commission (2024c).

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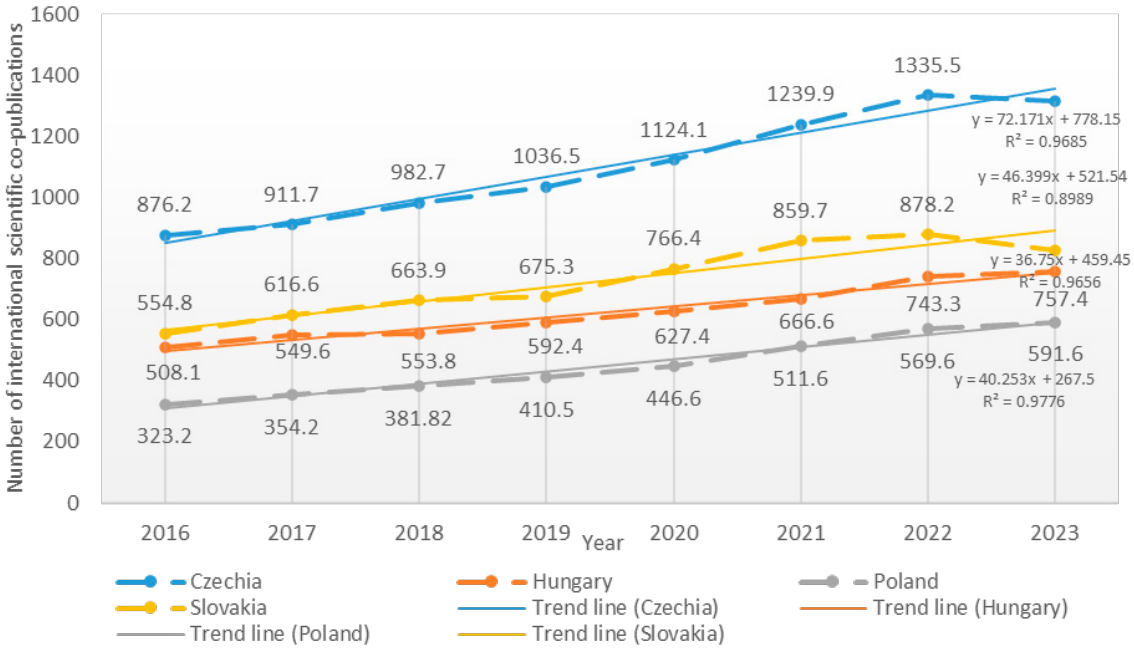

Figure 4. Number of international scientific co-publications per million population

Source: authors' work based on European Commission (2024c).

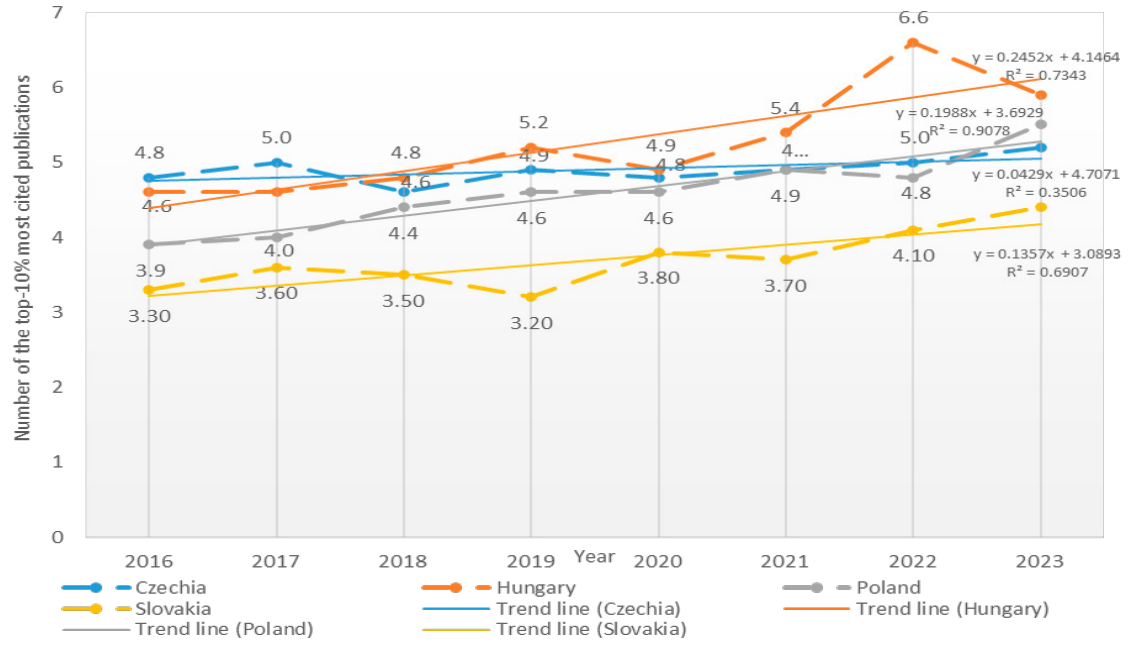

Figure 5. Number of the top-10% most cited publications (a percentage of total scientific publications of the country)

Source: authors' work based on European Commission (2024c).

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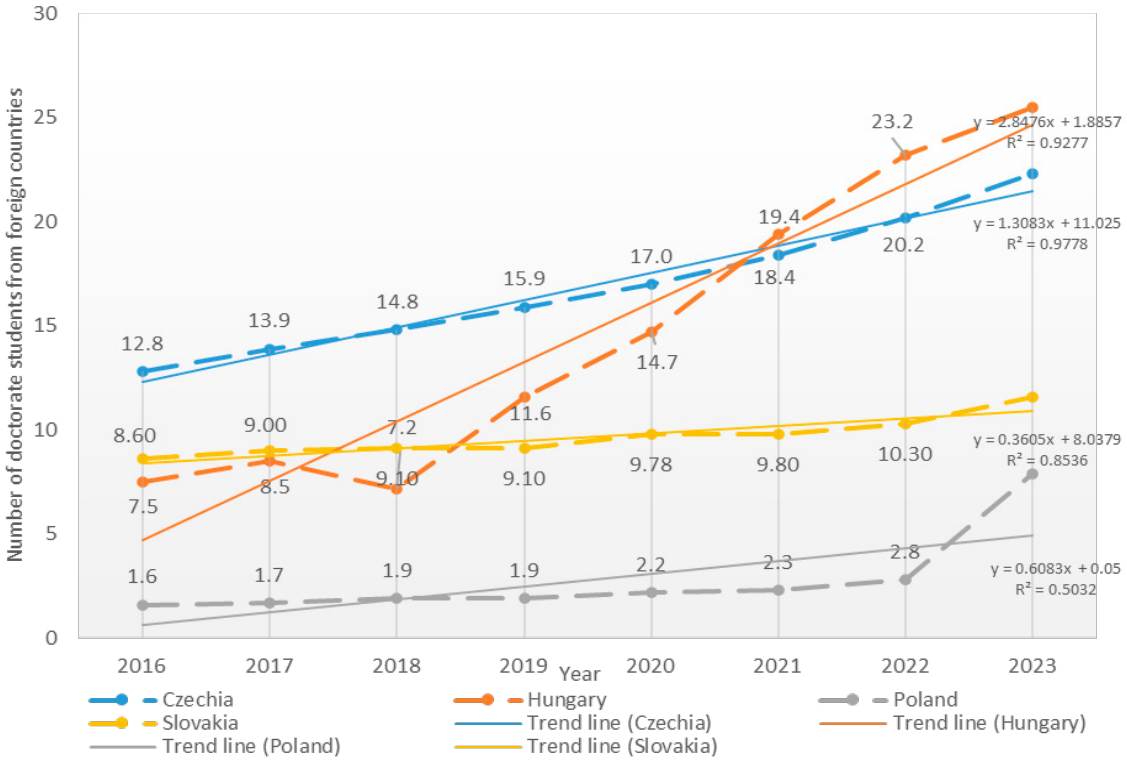

Figure 6. Number of doctorate students from foreign countries (a percentages of all doctorate students)

Source: authors' work based on European Commission (2024c).

The results also provide evidence of a significant gap between Poland and Czechia in terms of innovative SMEs collaborating with others and the number of public-private co-publications per million population over the period analysed. This may have implications for the limited resilience of Polish SMEs in challenging economic conditions. However, the results indicate that knowledge transfer between firms and other firms and between firms and the research system tended to increase in Poland in times of difficult economic conditions. This suggests an awareness of the importance of strengthening knowledge transfer in order to sustain or enhance the innovation activities of SMEs, thereby improving their resilience to challenging economic conditions. The increasing tendency of innovative SMEs to collaborate with others, together with the rising number of public-private co-publications per million population, is also observed for Hungary and Slovakia. This tendency should be seen as positive as it contributes to strengthening the resilience of SMEs.

Regarding the attractiveness of the research system, the results show that the Visegrad Group countries distinguish the attitude towards strengthening the competitiveness of the research system as crucial for knowledge transfer in challenging economic conditions (Figures 4–6). In this regard, the results imply that in terms of international scientific co-publications, top-10% of most cited publications and foreign doctorate students, especially Czechia and Hungary, stand out in the period 2016–2023. This suggests a greater attractiveness of the research system in these countries, offering stronger opportunities for firms to use knowledge transfer as a means of addressing market or environmental disruptions. The results also show that Poland has a lower level of knowledge creation by its research system compared to other Visegrad Group countries. This is evidenced by a lower number of international scientific co-publications per million population and the number of doctorate students from foreign countries. Similarly, Slovakia shows less knowledge creation, particularly in terms of the number of the top-10% most cited publications. This may indicate a limited capacity of the research system of these countries to facilitate the knowledge transfer necessary for SMEs to build resilience to economic shocks.

The analysis of innovation activities of the SMEs from the Visegrad Group countries during challenging economic conditions reveals that firms in Czechia consistently demonstrate the highest innovation performance throughout the period 2016–2023 (Figures 7–8). This is evident in both the

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percentage of SMEs introducing product innovation and the percentage of SMEs introducing business process innovation. It suggests a robust capacity for innovation, which enables Czech SMEs to adapt and thrive despite economic downturns.

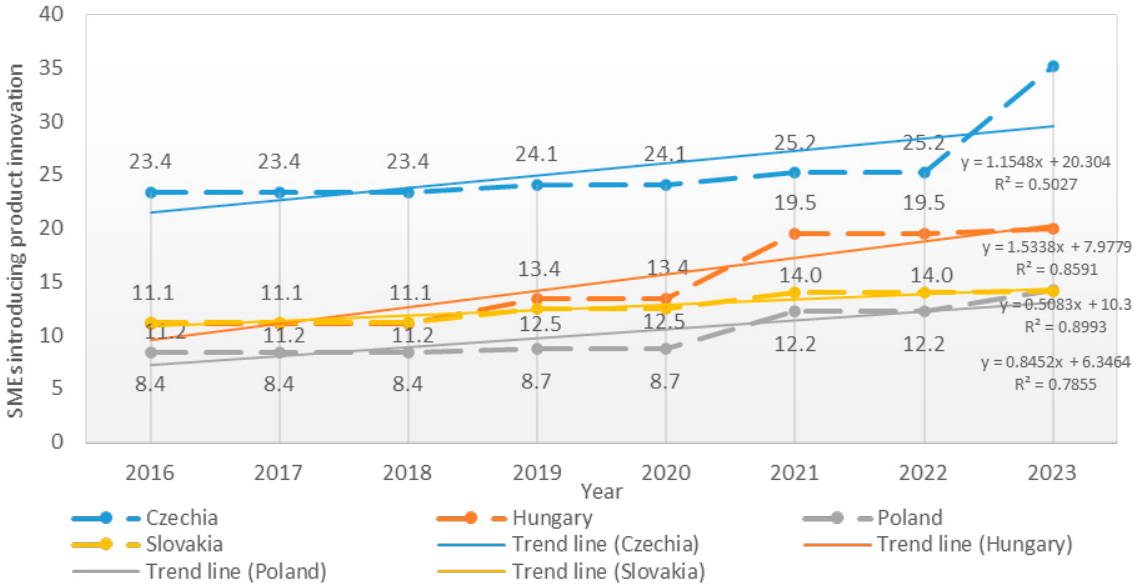

Figure 7. SMEs introducing product innovation (a percentage of SMEs)

Source: authors' work based on European Commission (2024c).

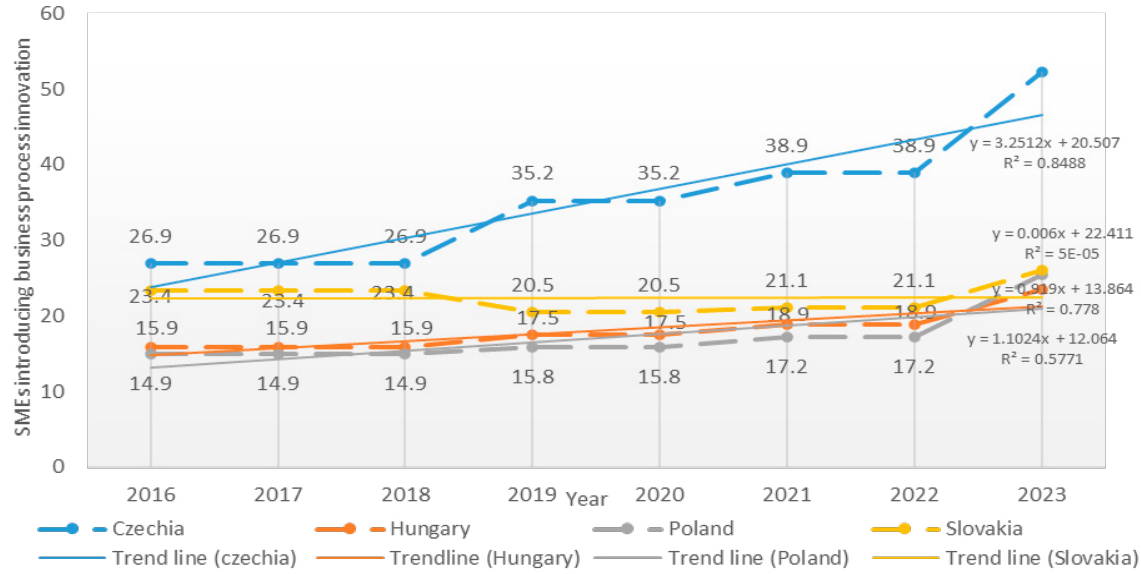

Figure 8. SMEs introducing business process innovation (a percentage of SMEs)

Source: authors' work based on European Commission (2024c).

The results provide evidence that Poland exhibits a lower percentage of innovative SMEs compared to the other Visegrad Group countries during the period analysed. This pattern is noticeable for SMEs' innovation activities related to product innovation and to business process innovation. The results also indicate that, similar to Poland, the low percentage of SMEs introducing business process innovation during the period under the study can also be observed in Hungary. However, it should be emphasised that despite the economic shocks that took place during the period 2016–2023, the percentage of innovative SMEs in all Visegrad Group countries tended to increase. This observation may indicate a growing resilience among SMEs, reflecting their ability to innovate despite challenging

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economic conditions. Such an increase should be viewed positively as it reflects the resilience of SMEs to difficult economic conditions, thereby contributing to the sustainable development of countries.

The results of zero unitarization method confirm the hypothesis that the Visegrad Group countries differ in terms of knowledge transfer as a feature of SMEs resilience to challenging economic conditions (Tables 2–3). In this context, the results reveal a relatively high diversity among the Visegrad Group countries.

Table 2. The classification of the Visegrad Group countries according to the level of knowledge transfer in 2016–2023 (part 1)

2016			2017			2018			2019		
No.	Co.	SM	No.	Co.	SM	No.	Co.	SM	No.	Co.	SM
Very High			Very High			Very High			Very High		
1.	Czechia	0.438	1.	Czechia	0.422	1.	Czechia	0.424	1.	Czechia	0.344
High			High			High			High		
1.	Hungary	0.337	1.	Hungary	0.318	1.	Hungary	0.334	1.	Hungary	0.286
Average			Average			Average			Average		
1.	Slovakia	0.314	1.	Slovakia	0.302	1.	Slovakia	0.312	1.	Slovakia	0.217
Low			Low			Low			Low		
1.	Poland	0.218	1.	Poland	0.204	1.	Poland	0.251	1.	Poland	0.185

Legend: Co. – country
Source: authors' work based on European Commission (2024c).

Table 3. The classification of the Visegrad Group countries according to the level of knowledge transfer in 2016–2023 (part 2)

2020			2021			2022			2023		
No.	Co.	SM	No.	Co.	SM	No.	Co.	SM	No.	Co.	SM
Very High			Very High			Very High			High		
1.	Czechia	0.393	1.	Hungary	0.337	1.	Hungary	0.277	1.	Hungary	0.262
High			High			High			2.	Czechia	0.253
1.	Hungary	0.348	1.	Czechia	0.329	1.	Czechia	0.246			
Average			Average			Average			Average		
1.	Slovakia	0.277	1.	Slovakia	0.222	1.	Slovakia	0.171	1.	Poland	0.209
Low			Low			Low			Low		
1.	Poland	0.245	1.	Poland	0.196	1.	Poland	0.133	1.	Slovakia	0.187

Legend: as in Table 2.
Source: authors' work based on European Commission (2024c).

The results show that the greatest diversity in knowledge transfer occurred between Czechia and Poland (2016–2020), Hungary and Poland (2021–2022) and Hungary and Slovakia (2023). Such diversity may have an impact on the ability of the SMEs from the Visegrad Group countries to be resilient in times of challenging economic conditions. The results indicate that the highest level of knowledge transfer distinguishes Czechia and Hungary – even in situations of inflationary pressures and the covid pandemic. This suggests that SMEs in Czechia and Hungary demonstrate a stronger

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ability to adapt to economic shocks compared to SMEs in Slovakia and Poland. The results also show that Slovakia maintained an average level knowledge transfer almost throughout the period considered, which can be interpreted as a positive factor contributing to the resilience of Slovak SMEs to difficult economic conditions. Compared to the other Visegrad countries, Poland stands out for the relatively low level of knowledge transfer over the period analysed. Such a situation may affect the ability of Polish SMEs to be resilient to economic shocks.

The results of the regression analysis are presented in Table 4.

Table 4. Estimation results

Variables	Czechia	Hungary	Slovakia	Poland
X_1	[a]	[a]	[a]	[a]
X_2	[a]	[a]	-0.003*** (0.001)	[a]
X_3	[a]	[a]	[a]	-0.001** (0.002)
X_4	[a]	-0.034** (0.013)	[a]	0.129* (0.059)
X_5	-0.022*** (0.003)	[a]	[a]	[a]
Constant	0.731*** (0.057)	0.492*** (0.072)	0.573*** (0.079)	-0.046 (0.159)
F	44.469***	6.337**	16.970***	3.881*
R-squared	0.881	0.514	0.739	0.608
Adjusted R-squared	0.861	0.433	0.695	0.451

Legend: [a] – variable not identified as most influential in forward stepwise regression. Heteroskedasticity and autocorrelation consistent. Standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01.
Source: authors' work based on European Commission (2024c).

Based on forward stepwise regression, the most influential variables associated with the best-fitting models were identified. While these variables varied across the Visegrad Group countries, the variable representing innovative SMEs collaborating with others (X_1) did not consistently emerge as one of the most influential variables in any of the models. The results suggest that in Czechia, the level of knowledge transfer during the period analysed is predominatly shaped by the attractiveness of the research system, in particular by the inflow of foreign doctoral students (X_5). A similar pattern is observed for Hungary, where the attractiveness of the research system, as indicated by the proportion of publications in the top 10% of most cited publications (X_4), was found to play a significant role in determining the level of knowledge transfer. In contrast, the results for Slovakia emphasise the role of linkages in determining the level of knowledge transfer, specifically knowledge transfer between firms and the research system, as measured by the number of public-private co-publications per million population (X_2). In the case of Poland, the results indicate that the level of knowledge transfer during the period analysed was shaped significantly by the attractiveness of the research system, as reflected in international scientific co-publications (X_3), and by the proportion of publications in the top 10% of the most cited publications (X_4).

The results of the regression analysis confirm the findings of the comparative analysis and the zero unitarization method, which provided evidence that the Visegrad Group countries differ in terms of knowledge transfer as a characteristic of SMEs' resilience to challenging economic conditions. However, it is noticeable that the coefficients, although statistically significant, are negative in almost all cases, indicating that the factors considered may tend to reduce the level of knowledge transfer. This result is unexpected, and the mechanisms behind it are not yet understood. A possible explanation for this negative relationship could be that, for example, the number of public-private co-publications per million population or the inflow of foreign doctoral students may not be sufficiently translated into practical applications of knowledge in the economic landscape. This suggests that the collaborations in question may be more formal or theoretical, without a substantial impact on the real implementation of knowledge. It is also possible that the observed effects reflect the

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peripherality and underdeveloped innovative infrastructure of the Visegrad Group countries, where the conditions for the effective use of knowledge in practice are not fully established. This could explain the negative coefficients observed in the results. The findings highlight the complexity of knowledge transfer, an understanding of which requires further investigation, particularly in terms of the quality of collaboration and its effective impact on knowledge transfer. Further research in this area could provide deeper insights into the dynamics between the variables used in the study.

Discussion

This study provides an insight into how the Visegrad Group countries differ in terms of knowledge transfer as a feature of SMEs resilience to challenging economic conditions, thus contributing to the broader discussion on the resilience of firms to economic shocks. The empirical results provide support for theoretical expectations that peripheral countries exhibit varying levels of knowledge transfer. This is in line with the findings of Grillitsch and Nilsson (2015). The findings reveal that Czechia stands out from the other Visegrad Group countries in its higher level of knowledge transfer during periods of inflationary pressures and the covid pandemic. This allows to conclude that despite the economic shocks that occurred between 2016 and 2023, Czech SMEs exhibited a particularly strong ability to withstand challenging economic conditions. As evidenced in the study, the other Visegrad Group countries show relatively lower levels of the knowledge transfer compared to Czechia over the period analysed. This finding supports the notion that different levels of knowledge transfer exist across the Visegrad Group countries, influenced by specific drivers, including the attractiveness of the research system.

Consistent with expectations, the findings provide evidence of a systematic increase in knowledge transfer in all Visegrad Group countries during the period analysed - even in the presence of inflationary pressures and the covid pandemic. This suggests that the knowledge transfer can be seen as an essential factor in enhancing the resilience of firms from the periphery to challenging economic conditions. This finding is in line with the argument of Pilav–Velic et al. (2024), who emphasise that knowledge transfer supports both innovation activities and the resilience of firms to economic shocks. The study also provides evidence of the systematic increase in the share of innovative SMEs among all SMEs in the Visegrad Group countries, supporting the conclusions of Destefansis and Rehman (2023) and Dovbischuk (2022) that innovation performance allows firms to be resilient to difficult economic conditions.

The empirical results confirm the hypothesis and reveal the relatively high diversity among the Visegrad Group countries in terms of: knowledge transfer between firms and other firms, between firms and the research system, and the attractiveness of the research system. This pattern is consistent throughout the period 2016–2023, suggesting a divergence in the extent to which conditions for knowledge transfer were created across the Visegrad Group countries. While knowledge transfer is widely regarded as a key driver of firm resilience to challenging economic conditions, such diversity may affect firm performance and, more broadly, the sustainable development of countries. A possible explanation for these variations lies in the argument about the different levels of development of knowledge transfer in each country and the incentives that encourage such cooperation. These results are similar to Rocchetta et al. (2022). In particular, the study shows that especially Czechia and Hungary stand out for their high potential for knowledge transfer, which was not only maintained but also increased during the economic shocks. This allows to conclude that these countries have a higher capacity for leveraging knowledge transfer to support firms' resilience to challenging economic conditions. These findings are consistent with previous research, in particular Añón Higón and Vicente-Chirivella (2024). The growing importance of knowledge transfer as a feature of SMEs resilience to economic shocks is also evident in Poland and Slovakia, although the differences in this respect are relatively large compared to the Czechia and Hungary. This indicates a growing awareness of the need to strengthen knowledge transfer mechanisms to help SMEs become more resilient to different economic conditions.

There are some limitations to the study that may suggest areas for future research. The study focuses on knowledge transfer variables related to linkages and an attractive research system. The selection of variables used in the study was driven by their ability to illuminate diverse facets of

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knowledge transfer and their consistency with previous research, particularly that of Azagra-Caro et al. (2018), Pinto and Guerreiro (2019) and Liu et al. (2023). However, due to the multifaceted nature of knowledge transfer, the study does not capture all the variables that could be used to describe this phenomenon. Thus, it would be valuable to investigate whether the results also apply to other variables describing knowledge transfer in the context of economic shocks. For example, the future studies could consider variables related to human resources, which are essential for knowledge transfer and firms' resilience to difficult economic conditions (Menéndez Blanco & Montes-Botella, 2017). In this regard, variables such as new doctoral graduates, the population aged 25-34 with tertiary education, and lifelong learning (European Commission, 2024c) could be considered. Next, the study employs the comparative analysis and taxonomic method, specifically zero unitarisation method. Even though these methods are confirmed by their usefulness in prior studies that compare objects and phenomena, as well as analyse differences across regions and countries, future research could benefit from exploring other methodological approaches. This could allow for further understanding of issues related to knowledge transfer and the resilience of SMEs in the peripheral countries in challenging economic conditions. In this regard, comparative case studies may be particularly useful, as such studies enable the examination of two or more cases in greater depth, facilitating a more comprehensive comparison and understanding within and across contexts (Goodrick, 2014). Another limitation of this study is that it does not explore the underlying causes of the significant diversity in knowledge transfer practices among the Visegrad Group countries. Investigating factors such as variations in institutional frameworks, innovation policies and levels of economic development could provide deeper insights into how these contextual factors influence knowledge transfer and consequently firm resilience in these countries. It could be interesting, for instance, to examine the differences in the regulatory environment for knowledge transfer between the Visegrad Group countries. An analysis of the framework conditions for public-private knowledge cooperation in these countries could also be valuable. Similarly, future studies should also examine the differences in national innovation strategies within the Visegrad Group countries and their ability to promote and enhance knowledge transfer. Additionally, it would be valuable to analyse the economic development of the Visegrad Group countries, as more economically developed countries are likely to allocate more resources to research and development activities (Nast et al., 2024) and create conditions that foster highly skilled human resources (Huggins & Kitagawa, 2011), which are crucial for knowledge transfer.

Furthermore, although the study focuses on the period 2016–2023, during which SMEs from the Visegrad Group countries faced difficult economic conditions such as inflationary pressures and the covid pandemic, it seems worthwhile to conduct research that considers a longer time frame. Future research should view this limitation as a potential opportunity to identify long-term trends related to knowledge transfer and the resilience of SMEs. This could offer a more comprehensive understanding of firms' resilience to economic shocks. Finally, the study focuses on the Visegrad Group countries as peripheral countries within the European Union. These countries emphasise geographical proximity, similar cultural backgrounds, and the same transition time from centrally planned to market economies. It would be interesting to examine whether the results obtained also apply to other peripheral countries in the European Union. This highlights the need for future studies on knowledge transfer and the resilience of SMEs to challenging economic conditions, covering other peripheral countries within the European Union.

Conclusions

This article contributes to the growing body of research on the resilience of firms to challenging economic conditions, particularly in relation to their innovation activities and, more broadly, to the sustainable development of countries. The study focuses on knowledge transfer as a key driver of firm resilience to economic shocks, with particular attention given to SMEs from peripheral countries. Specifically, it examines knowledge transfer through collaboration between firms and other firms, and between firms and the research system in the Visegrad Group countries. In addition, the study highlights the importance of an attractive research system as a crucial factor in facilitating knowledge transfer and enhancing the resilience of SMEs in the face of economic challenges. The results show significant diversity among the Visegrad Group countries in terms of knowledge trans-

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fer in the period 2016–2023, when SMEs in these countries faced inflationary pressures and the covid pandemic. The study also highlights the high potential of SMEs in Czechia and Hungary in the area of knowledge transfer, which can strengthen the resilience of SMEs from these countries to economic shocks and enhance their competitiveness. The findings also suggest that, despite having relatively average or low levels of knowledge transfer, Slovakia and Poland were making systematic improvements in this area. This progress could help to improve the ability of firms in these countries to withstand market or environmental disturbances.

This study has several implications for scholars and policymakers interested in both the resilience of SMEs to economic shocks and the factors that promote sustainable development of regions and countries. First, it contributes to the stream of literature exploring the relevance of knowledge transfer in the survival and development of SMEs by highlighting the importance of knowledge transfer in the resilience of SMEs to challenging economic conditions. Second, the study adds to the growing body of literature on the ability of regions and firms to withstand market or environmental disturbances by providing a deeper insight into the divergence in knowledge transfer among the peripheral countries that share similar cultural backgrounds and have undergone the transition from centrally planned to market economies at the same time. Third, the study contributes to the research on how the concept of knowledge transfer could be conceptualised and measured through the use of a synthetic index that provides a coherent picture of the levels of this transfer during challenging economic conditions. For policymakers and regional and national development agencies, the study provides recommendations on the need to strengthen the conditions that facilitate knowledge cooperation, thereby supporting knowledge transfer and helping SMEs to better cope with challenging economic conditions and therefore promote sustainable development of regions and countries. A key focus should be on further enhancing incentives for firms to share and apply knowledge. For example, funding from European Union programmes such as Horizon Europe, which focuses on research and innovation, could be essential to foster knowledge transfer between firms and other firms, and between firms and the research system (Saha et al., 2023). National and regional authorities should encourage and support firms in applying for European Union funding, which can strengthen knowledge cooperation and enhance the resilience of firms to challenging economic conditions.

The contribution of the authors

Conceptualisation, A.Z. and J.Z.; literature review, A.Z. and J.Z.; methodology, A.Z. and J.Z.; formal analysis, A.Z. and J.Z.; writing, A.Z. and J.Z.; conclusions and discussion, A.Z. and J.Z.

The authors have read and agreed to the published version of the manuscript.

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TRANSFER WIEDZY JAKO CECHA ADAPTACJI MAŁYCH I ŚREDNICH PRZEDSIĘBIORSTW DO TRUDNYCH WARUNKÓW GOSPODARCZYCH: PRZYKŁAD KRAJÓW PERYFERYJNYCH

STRESZCZENIE: Celem artykułu jest zbadanie, czy i w jaki sposób kraje peryferyjne różnią się pod względem transferu wiedzy jako cechy odporności małych i średnich przedsiębiorstw na trudne warunki gospodarcze. Badanie koncentruje się na krajach Grupy Wyszehradzkiej, które są należą do krajów peryferyjnych Unii Europejskiej, oferując unikalny kontekst badawczy ze względu na ich podobne tło kulturowe i rozpoczęcie transformacji gospodarki centralnie planowanej do rynkowej w tym samym czasie. Badanie obejmuje lata 2016–2023, które cechowało występowanie presji inflacyjnej oraz pandemii covid. Do przetestowania hipotezy wykorzystano analizę porównawczą i metodę unitaryzacji zerowanej. Wyniki pokazują, że chociaż istniały znaczne różnice w poziomie transferu wiedzy w badanych krajach peryferyjnych, wszystkie kraje Grupy Wyszehradzkiej wykazały stałą tendencję wzrostową w zakresie transferu wiedzy w analizowanym okresie. Otrzymane rezultaty stanowią wkład do rosnącej liczby badań nad odpornością firm na trudne warunki gospodarcze sugerując, że transfer wiedzy w regionach peryferyjnych służy jako mechanizm zwiększający odporność firm na zakłócenia rynkowe lub środowiskowe, a w szerszym kontekście wpływa na zrównoważony rozwój krajów.

SŁOWA KLUCZOWE: transfer wiedzy, trudne warunki gospodarcze, kraje peryferyjne, Grupa Wyszehradzka, odporność, zrównoważony rozwój

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