The role of cluster organisations in stimulating cooperation between business and science. Experience from the Visegrad Group countries

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Cooperation between science and business is regarded as a prerequisite for the development of innovation. The aim of this article is to provide a holistic view on the nature of business-research relations in cluster organisations in the Visegrad countries, by assessing their role in promoting this cooperation and identifying its determinants and barriers. The recognition of cluster organisations as a driver of innovation is connected with the fact that they create an environment conducive to cooperation, building trust between their members and reducing numerous barriers that limit it. This paper examines the role of cluster organisations in stimulating cooperation between business and science, providing a comparative analysis of the Visegrad countries in this respect. On the basis of in-depth interviews with managers of cluster organisations, and a survey of representatives of science-sector institutions, the authors clarified the role of cluster organisations in this process. Barriers were also diagnosed, such as the capacity constraints of R&D&I in SMEs, the cost of cooperation due to administrative overheads, differences in the organisational interest and culture. The study sheds new light on the role of cluster organisations and their members, showing that the 'strategic innovators' are critical to science-business cooperation. The research findings may inspire cluster organisation managers and other actors to create a common innovation ecosystem and approach, as well as encourage cluster organisation companies to implement joint research projects together with research organisations, which will result in mutual benefits for the parties involved.

1. Introduction

After World War II, and with the establishment of Pax Americana, Western European countries began rebuilding their position on international markets, which was fuelled by their deepening integration, leading to the establishment of the European Union (EU). Almost six decades later, namely in 2004, the EU grew and welcomed ten new Member States. Four of them – the Czech Republic, Hungary, Poland, and Slovakia – members of the Visegrad Group (V4) since 1991 (before becoming sovereign states in 1993 the Czech Republic and Slovakia formed part of the Visegrad Group as Czechoslovakia) – had already been cooperating with each other, with the aim to convert the chasm between their level of development and that of the EU into merely a gap.

Although the differences between them and the EU have become less apparent in many areas since 2004, in some they still exist, and innovation is one of the examples where disparities have not effectively been eliminated. To remain at the forefront of global competition the EU has focused on innovation as one of its core strategic goals. The V4 countries became Member States during the decade of the Lisbon Agenda, yet up till now they are not among the EU frontrunners in innovation.

In 2021 the Czech Republic was 17th in the European Innovation Scoreboard, while Hungary, Slovakia, and Poland were 22nd–24th, respectively (EIS database 2021). The same or similar order can be observed throughout other rankings or types of data on innovation, e.g. the 2019 World Competitiveness Report (Schwab 2019) in which within the 12th pillar – Innovation capability – the Czech Republic was ranked as the 29th most innovative country in the world, Poland came 39th, Hungary – 41st, and Slovakia – 44th. These rankings resulted from a set of internal circumstances shaping their innovation ecosystems, including those related to research and development (R&D). In 2018 R&D expenditure stood at 1.93% of GDP in the Czech Republic, 1.55% in Hungary, 1.21% in Poland, and 0.83% in Slovakia (World Bank database). When investigating further the issue of R&D development across the Visegrad group, the state of university-industry cooperation in R&D can be perceived as an impeding factor, especially in the case of Hungary (ranked 59th in the Global Competitiveness Ranking), Poland (90th) and Slovakia (98th), while the Czech Republic ranked 38th (Schwab 2019).

The importance of the undertaken topic is connected to the fact that the development of clusters and cluster organisations is particularly important for Visegrad countries that are in the process of continuous change in terms of their institutional setting. Moreover, their innovation systems are classified among developing innovation systems, one of whose main weaknesses is poor cooperation among companies as well as between the science and business sectors, which is a legacy of the country's former central planning system.

The transfer of technology from the science sector to the economy and society is an element through which universities can make an extremely valuable contribution

to economic development. However, if it is missing, or if it fails to deliver the desired results, increased innovation is less likely to be achieved. Research organisations are an important element of the economy embedded in the Porterian cluster concept, in which the linkages between companies and universities are a source of positive externalities. That is why cluster organisations are often recognised as important elements of innovation ecosystems, as they consist of companies and science sector institutions, business environment institutions, and public entities. Their unique role is centred on bringing together actors representing different backgrounds.

Cluster organisations have been operating across the Visegrad group since the beginning of this century. However, despite the multi-dimensional proximity between these countries, as well as the influence of the EU on introducing cluster policy in all of them, many questions regarding the processes occurring within cluster organisations still remain unanswered, and problems unsolved. The research gap on the extent to which they have been able to provide tangible results is gradually narrowing. However, the topic of how the relations between business and science are built and maintained remain understudied.

The aim of this paper was to provide a holistic view on the nature of business--research relations in cluster organisations in the Visegrad countries by assessing their role in promoting this cooperation and identifying its determinants and barriers. The empirical findings first focused on presenting the main actors embedded in the cooperation. The authors' focus then shifts to the relevance of this cooperation, the role of cluster organisation managers in it and barriers which are the main inhibitors of business-research cooperation in cluster organisations across the Visegrad zone.

The data used in this paper were collected under the project "Clusters as platforms for business-research (B2R)/research-business (R2B) relations co-financed by the Governments of Czech Republic, Hungary, Poland and Slovakia" financed through Visegrad Grants from the International Visegrad Fund (Visegrad Fund project No. 22030333). The project was designed with the assumption that understanding cooperation between members of cluster organisations (business and research) could improve the level of innovativeness of the V4 countries.

2. Literature review

Clusters have grown in importance as a research topic, with cluster structures being considered as an important factor stimulating science-business cooperation, and consequently innovation activity. The significance of clusters for technological development is connected to the fact that innovation activity, particularly in high--tech industries, tends to be geographically concentrated, usually around metropolitan regions and specialised clusters (Kowalski, 2022). There has been a growing recognition of the importance of the regional perspective in innovation processes, and the literature emphasises the critical role of collaboration and networking in

innovation activities, demonstrating its beneficial effect on innovation performance (Wang and Hu, 2020). Knowledge, a critical component of innovation, spreads more effectively when actors in the innovation process are in proximity, which may be analysed not only geographically but also cognitively, organisationally, socially, and institutionally (Boschma, 2005).

In order to investigate the role of cluster organisations in stimulating cooperation between business and science, it is important to define three terms. The first definition is related to clusters that are "geographic concentrations of interconnected companies, suppliers, service providers, firms in related industries, and associated institutions (e.g. universities, standards agencies, and trade associations), in particular fields that compete but also cooperate" (Porter, 1998, p. 197). Clusters should be distinguished from cluster initiatives, the latter being "organised efforts to enhance the competitiveness of clusters within a region, involving cluster firms, government and/or the research community" (Sölvell et al., 2003, p. 9). This leads to the term of cluster organisation, which may be defined as "a legal entity dealing with managing a cluster initiative, including developing rules for taking part in joint operations and gaining access to a shared infrastructure" (Kowalski, 2016, p. 226). The majority of papers discuss cooperative developments inside clusters, not within cluster organisations. However, cluster organisations may act as mediators for open innovation, as with research institutes being members of cluster organisations it is easier for companies to use scientific knowledge.

The absorption of external knowledge constitutes an input to companies' innovation activities in clusters. There is a two-way relationship: the open innovation of businesses can determine the creativeness and complexity of a cluster, whereas the openness and creativity of a cluster affect the level of open innovation among its members (Kowalski and Mackiewicz, 2021). Research and development entities transfer the results of their R&D work to companies in the form of knowledge and innovative solutions or inventions, while receiving financial resources and supplementing theoretical knowledge with the possibility of its use in practical business activities and adapting them to the realities of industry (Kowalski, 2010). Businesses and other units close by make it easier for partners to engage and communicate, which adds significant value and has many positive synergistic effects. Cooperation between various cluster participants is helpful for the creation and assimilation of innovations, transfer of technology, flow of knowledge, and continual learning (Bittencourt et al., 2022). As trust is developed between cluster members based on shared objectives, clusters provide a good environment for the flow of knowledge.

The current paradigm in the economics of innovation states that the driving force for successful innovation activity are the interactions and cooperation among three categories of actors, as defined in Etzkowitz and Leydesdorff's (1995) Triple Helix model: industry, university and government. According to this approach, the boundaries between science and industry are eroding, which results in a system

of overlapping interactions (Pique et al., 2018) engaging universities as the knowledge-generation subsystem, and industry as the knowledge-exploitation subsystem. University-business interaction is still a fragmented and understudied area of research, and knowledge of this cooperation is still insufficient, despite the rising acceptance of the potential for The Triple Helix to contribute to the creation of an innovative economy (Galan-Muros and Davey, 2019). The shift from a closed to open model of innovation is a crucial issue in the development of the present model of cooperation between universities and businesses in the field of technology transfer. For entrepreneurs, utilising the outcomes of scientists' R&D work and outlining the directions of research on novel solutions with high commercialisation potential becomes particularly essential (Rybicki and Dobrowolska, 2018). Universities are being increasingly recognised as a source of human capital, as well as technology and innovation, which reflects university-business cooperation in research and education (Orazbayeva et al., 2020). As they play an increasingly significant role in technology transfer and the marketing of information, university-business cooperation is seen as essential to regional economic progress and social prosperity (Ripoll Feliu and Diáz Rodriguez, 2017).

The dispersion of information and capital in the modern world have led to efficient innovation activity being based not just on an organisation's internal resources but also on an appropriate mix of knowledge, skills, and activities from multiple players that form cluster organisations. Knowledge creation and other forms of innovative activity are more successful in clusters because they frequently include universities and R&D facilities. Organisations may profit from lower costs connected with receiving external information from regional academic partners when compared to the potential expenses of internal knowledge development or acquisition from units located at a significant geographic distance. Clusters are essential for the ongoing transfer of knowledge and technology from science to industry as they create enduring links between the two fields. In cooperative processes, interpersonal relationships, which clusters favour, are vital, especially when it comes to the transmission of tacit information that requires face-to-face interaction (Karlsson and Andersson, 2009).

University-business cooperation, in particular in the framework of cluster organisations, should be considered an important element among other factors positively driving the propensity of a firm to innovate, such as (Abdu and Jibir, 2018): research and development (R&D), employees' education level, training, the firm's size and age, exporting status, competitors, location, type and sector. While novel technologies may demonstrate significant competitive potential, they also involve certain risks, which decreases in line with with technology maturity. This reflects the technology life cycle model, in which technology is conceptualised as a cycle wherein capabilities and competitiveness rise and decay over time (Lezama--Nicolás et al., 2018).

3. Research methods

In this article the authors sought to answer the following questions:

 (i) What is the role of cluster organisations in fostering science-business cooperation?

 (ii) Which cluster organisation actors play the main role?

 (iii) What are the determinants and barriers of cooperation?

The study was based on a mixed research strategy: a sequential exploratory design in which the first stage was qualitative research, and the second stage involved quantitative research. The reason for using a mixed strategy and the associated logic of triangulation in this study was the need to obtain a broad picture of the issues being analysed. The order in which the two distinctive research stages were carried out resulted from the objectives guiding the research. To investigate the role of cluster organisations in research-business relations, to identify the forms of cooperation that work well, and to identify the factors that may determine its forms and scope of cooperation, semi-structured in-depth interviews with cluster organisation managers were carried out. The respondents were selected through purposeful sampling based on expertise regarding cluster organisation management in coordinating research activities. The sample consisted of 44 cluster organisations (COs) distributed among the V4 countries, as presented in Table 1.

Table 1

Description of the sample

Country	Number of COs registered on the ECCP platform	Number of COs in the research sample	Justification of the sample selection
Czech Republic	21	10	Members of the National Cluster Association, having at least three research organisations as members
Hungary	26	10	Accredited Cluster Organisations (reduced sample)
Poland	71	15	Certificate of a National Key Cluster (full sample)
Slovakia	24	9	Active cluster organisations labelled by the European Secretariat for Cluster Analysis

Source: https://clustercollaboration.eu/ and own work (accessed: 11.09.2022).

The interviews were conducted between May and September 2021. Based on the results it was assumed that the sample size was appropriate to reach saturation (Boddy, 2016). The respondents were suitably qualified and provided accurate

representation of how their organisations perform. With regard to their main activity, cluster organisations represented fourteen different fields, and their distribution across them was the following: ICT – 9 COs; production and engineering – 7 COs; energy and environment – 5 COs; health and medical science – 4 COs; 3 COs each belonged to the following fields: (a) mobility: vehicles, rail, traffic systems, (b) new materials and chemistry, (c) aviation and space; 2 COs each pertained to (a) construction, (b) creative industries; and in the case of (a) biotechnology, (b) logistics: packaging, delivery, logistical systems and services, (c) production and engineering & logistics: packaging, delivery, logistical systems and services, (d) textile industries, (e) transportation and mobility the study was conducted in one CO each.

To further explore cooperation from the perspective of the science sector, a survey was carried out with the employees of research organisations that deal directly with companies belonging to cluster organisations; this step was undertaken to assure informants' triangulation at the data collection stage. Almost all cluster organisations participating in the study had at least one research organisation among their members. The respondents were indicated by cluster organisation managers (the researchers asked for contact persons during the interviews). The number of complete answers to the survey was 46. The survey allowed to assemble detailed information on the number of joint projects, timeframe, their results, etc. and provided a perspective of the science sector on the determinants and barriers of cooperation. The responses to the survey were the subject of quantitative analysis. A set of indicators was used for comparative analysis between the V4 countries. All the interviews were transcribed, coded, grouped and were the subject of qualitative analysis.

4. Findings

4.1. Actors

Cluster organisations in the Visegrad countries have different membership structures. Poland stands out with the largest cluster organisations and the largest number of science sector institutions among their members. Slovakian cluster organisations, on the other hand, include a relatively large number of public institutions and NGOs, and the number of large enterprises operating in Slovakian cluster organisations is similar to the number of SMEs (Table 2).

The structure of the cluster organisation itself is not as important for science-business cooperation as the number of companies identified in the study as 'strategic innovators', which are companies that conduct R&D work on a continuous basis. Intuitively, it can be assumed that the more science sector institutions there are in a cluster organisation per company, the greater the chances of cooperation. However,

Table 2

Structure of cluster organisation members by country

Country		Firms: SMEs	Firms: large	Educational institutions: high schools	Educational institutions: universities	Research institutes	Public institutions	NGOs
Czech Republic	mean	28.9	11.6	2.2	3.2	2.2	1.0	1.0
	median	26.0	7.0	2.0	3.0	2.5	1.0	1.0
Hungary	mean	36.7	1.9	0.4	2.2	0.6	0.2	0.5
	median	35.5	1.5	0	2.5	0.5	0	0.5
Poland	mean	**102.4**	**16.4**	0.6	**6.9**	**7.1**	1.7	2.8
	median	**87.0**	12.0	0.0	**7.0**	**6.5**	2.0	2.0
Slovakia	mean	13.7	13.0	**18.0**	3.1	1.6	**3.3**	**3.0**
	median	15.0	**13.0**	**18.0**	3.0	1.0	**3.0**	**3.0**

Source: own work based on a database collected for the purpose of the project "Clusters as platforms for business-research (B2R)/research-business (R2B) relations" (Visegrad Grant No. 22030333) accessed June 30th 2022 [N=44].

statistical analysis has not confirmed this relationship, and there is no correlation between the ratio of the number of science sector institutions and the number of enterprises in a cluster organisation. There is, however, a significant correlation between the share of 'strategic innovators' and the share of cluster organisation members that have been actively involved in R&D&I cooperation between firms and science sector institutions (correlation coefficient $r = 0.51$; p-value $= 0.00048$).

4.2. Engagement of cluster organisation managers

Cluster organisations are established with the intention of achieving multiple goals. In general, they provide the opportunity for networking and cooperation while bringing together various actors. In doing so they are led by managers who are responsible for running not only daily activities, but also co-designing the strategy of the organisation and its future endeavours. Cluster organisation managers have a distinct and wider perspective than regular cluster organisation members. They present a simultaneous outlook at various processes within the cluster organisation, while its members are mostly focused on their company or organisation and those entities with whom they cooperate.

When asked about cooperation initiation between research and business in cluster organisations the managers across the Visegrad group provided a distinct overview on the matter (Table 3). What significantly characterises Slovakia is the largest share of research-business cooperation initiated by cluster organisation managers, which most probably stems from the following reason – Slovakian cluster organisations were 'the youngest' in the sample, and their cluster organisation managers are still very actively engaged in establishing relations between cluster organisation members.

In the remaining three countries cluster organisations had been established before their Slovakian counterparts. As a result, many cluster organisation managers from the Czech Republic, Hungary, and Poland stated that they are aware of the fact that research-business cooperation in their cluster organisations sometimes takes place without their knowledge or engagement due to the maturity of relations previously established between cluster organisation members. Another conclusion from a comparative analysis of the data is related to research organisations engagement in establishing cooperation with business. Whilst in Slovakia R2B (research-to-business) cooperation seldom occurs, in Hungary, Poland and the Czech Republic research organisations are more active in this area.

Table 3

Initiation of cooperation between business and research in cluster organisations from the perspective of cluster organisation managers

Country		Entity responsible for cooperation initiation		
		Cluster organisation management	Business	Research organisations
Czech Republic	min	0%	20%	0%
	mean	35%	46%	19%
	median	38%	50%	22%
	max	50%	100%	50%
Hungary	min	0%	10%	0%
	mean	31%	38%	31%
	median	37%	34%	20%
	max	60%	90%	75%
Poland	min	0%	30%	0%
	mean	18%	60%	22%
	median	10%	58%	25%
	max	70%	100%	50%
Slovakia	min	30%	0%	0%
	mean	61%	27%	11%
	median	50%	30%	10%
	max	100%	60%	20%

Source: own work based on a database collected for the purpose of the project "Clusters as platforms for business-research (B2R)/research-business (R2B) relations" accessed June 30th 2022 [N=44].

Once initiated, cooperation comes in many forms. Two types of cooperation are almost universal across the Visegrad group, namely: (a) information exchange fora (existing in all Czech and Hungarian cluster organisations, in 93% of Polish and in 78% of Slovakian cluster organisations) and (b) participation in seminars, conferences, exhibitions, and fairs. Other types of cooperation are not as evenly chosen.

Whereas in the Czech Republic and Poland the use of research organisations or industry facilities is very common, in Hungary and Slovakia it occurs significantly less often. Liaison offices in research organisations or in companies are established in 80% of Czech and 70% of Hungarian cluster organisations, and their occurrence is around half less common in the remaining two Visegrad countries. Cooperation centred around R&D&I projects (either domestic or international) occurs most often in Poland (in almost all cluster organisations) and it is less prominent in the Czech Republic, Hungary, and Slovakia (the percentage of cluster organisations reporting this type of cooperation are above 70%). Cooperation that engages students (either in the form of internships or their participation in company's projects) is distinctly less prominent in Slovakia. Finally, staff mobility is a very infrequent form of cooperation between business and research, except in Poland, where it is reported by 80% of cluster organisations.

4.3. Barriers in cooperation

Assessment of the role of cluster organisations in supporting cooperation between science and business required identification of barriers that limit this cooperation. The question was whether the cluster organisation manager undertakes any actions to reduce these barriers. In the analysed cluster organisations, four barriers, indicated by more than half of the respondents, turned out to be the most significant: (a) capacity constraints of R&D&I in SMEs indicated by 58% of respondents, (b) cost of cooperation due to administrative overheads (57.5%), (c) organisation interests and culture i.e. differences between the world of science and industry (55%), (d) organisation structure (research institution/university administrative structure and firm structure), indicated by 53.6% of the respondents.

Two of the identified barriers are related to the SME's ability to finance research and dedicate appropriate staff to this cooperation. SMEs often prefer to decide to buy ready-made solutions, even if they are not ideally suited to their needs, because they do not have appropriately qualified personnel dedicated to cooperation with science sector institutions. On the other hand, SMEs do not generate high enough profits to use the services of scientific entities. Therefore, science sector entities see the capacity constraints on the side of SMEs, and in SMEs the prevailing view is that commissioning R&D work is associated with very high costs and a relatively long waiting time for the results. Cluster organisation managers can help to overcome these barriers – by correctly recognising the needs of both sides, the manager can reduce stereotypical thinking on both sides and lead to an agreement.

The second group of barriers is related to the characteristics of the entities that cooperate, as well as their objectives. Companies operate for profit and tend to have a flatter organisational structure. The objectives of scientific institutions are quite different, and their hierarchical structure makes it difficult to access decision-makers, which potentially prolongs the whole procedure and respectively – implementing the

research results, which is an understandable obstacle for enterprises. Yet again, the cluster organisation manager facilitates contact with decision makers and provides a framework for cooperation, at least on the formal side.

Table 4

Top three barriers in science-business cooperation by country

Czech Republic	Hungary	Poland	Slovakia
(1) Capacity constraints of R&D&I in SMEs, (2) Organisation structure (RO/UNIV administrative structure and firm structure), (3) Capacity and fields of research of RO/UNIV in relation to needs of firms in cluster organisations	(1) Organisation structure (RO/UNIV administrative structure and firm structure), (2) Cost of cooperation due to administrative overheads, (3) Difference in organisation interest and culture	(1) Cost of cooperation due to administrative overheads, (2) Organisation structure (RO/UNIV administrative structure and firm structure), (3) Difference in organisation interest and culture	(1) Capacity constraints of R&D&I in SMEs, (2) Organisation structure (RO/UNIV administrative structure and firm structure), (3) Insufficient financial resources

Source: own work based on a database of in-depth interviews with cluster organisation managers collected for the purpose of the project "Clusters as platforms for business-research (B2R)/research-business (R2B) relations" (Visegrad Grant No. 22030333) accessed June 30th 2022 [N=44].

With regard to the barriers in cooperation, some differences between countries can be observed. Poland and Hungary have similar top three barriers, and Slovakia's resemble those of the Czech Republic's (Table 4).

4.4. Importance of cooperation and solutions to foster B2R collaboration

The importance of cooperation with research institutions on the technological progress of cluster organisation member-firms was evaluated by cluster organisation managers. It was assessed ambiguously, although rather positively. In Hungary two cluster organisations gave the answer that this cooperation is not important for the technological progress of companies. Two more answers indicating the low importance of this cooperation were also given by Hungarian cluster organisations. In the other countries a total of 44% of the cluster organisations surveyed considered that cooperation between science and business is important or very important for the technological progress of companies.

Some of the studied cluster organisations have developed solutions to foster collaboration between companies and research organisations. Several best practices were identified in the Czech Republic. Among them two play a vital role in fostering business and research collaboration, including: creation of working groups that focus on discussions concerning R&D projects, and of centres of experts that work on R&D ideas and transform them into joint research projects (Clusters as platforms…,

2022a). Examples of best practices in Hungary include, but are not limited to, creation of a living lab network to connect knowledge partners with the aim of developing Industry 4.0 in the food industry; designing and providing IT trainings to small and medium-sized companies; creation of a knowledge centre focused on providing training, education, and research services; creation of a shared physical infrastructure hub for ICT companies; creation of a start-up mentoring programme and idea contest; a call for innovation projects, including cooperation between cluster organisation members (Clusters as platforms…, 2022b). Best practices among cluster organisations in Poland include: the establishment of a non-profit research institute; the establishment of a platform of collaboration bringing together various entities within a cluster organisation, the actions of which include creation of working groups, conducting joint research projects, working on new technologies, and providing technical assistance; creation of a tool to assess the economic condition of cluster organisation members; creation of thematic platforms, etc. (Grzybowska-Brzezińska et al., 2022). Among Slovakian cluster organisations one particular best practice was identified. It entails the organisation of Innovation Days, during which various opportunities of collaboration between research organisations and companies are discussed (Clusters as platforms…, 2022c). In general, best practices across the Visegrad group can be either permanent or take a project-based form, while the main aim of all of them is to provide services that efficiently target the needs of cluster organisation members.

5. Discussion

Cluster organisations represent a shift in the paradigm in the conventional approach to cooperation between science and business, especially in the context of technology transfers from R&D units to industrial companies which implement the findings of R&D in real economic activity. To create new ideas and raise the degree of innovation, relations, and interactions between these units within cluster organisations, they form a system in which businesses with restricted access to knowledge can transfer it from outside sources (Molina-Morales et al., 2021). According to this approach, by connecting local units through a network of formal and informal contacts, it is easier to conduct joint research and development projects, share expertise and information, and trade cutting-edge technical solutions. In the current scientific paradigm universities' primary functions are not research and development or teaching, but rather complex influence on the economy and bringing value added to emerging industrial sectors (Hershberg et al., 2007). Cluster organisations make it easier for R&D, educational, and industrial entities to cooperate, and they also put this cooperation more in the perspective of innovations, new business ventures, and information transfer (Qian, 2022).

There are two approaches to examine how cluster organisations affect the development of interactions between research and the economy. On the one hand,

cluster arrangements increase the chances of entrepreneurs obtaining access to the outcomes of R&D projects, allowing them to engage in and grow creative economic activity. On the other, clustering improves the incentives for scientists to conduct R&D projects in line with market demands. These mechanisms raise the degree of technical supply and demand matching and boost the demand for technologies developed as a consequence of R&D activities. Continuous cooperation between the creators and recipients of new solutions facilitates the extensive spread of innovation and produces synergistic effects, enabling the achievement of goals that are not possible for one actor to achieve alone (Turkina et al., 2019).

The results of the research show that cooperation with research institutes positively influences the technological advancement of the companies that make up the cluster organisation, which is consistent with the findings of other researchers (e.g. Kowalski, 2013; Ferras-Hernandez and Nylund, 2019; Alberti et al., 2021). However, considering the developing nature of national innovation systems in the V4 countries, and the growing stage of development of many cluster organisations, many challenges and barriers in science-business cooperation appear. Building the capacity to enhance information flow among existing members, while also being reachable to newcomers, is one of the biggest challenges facing innovation networks (Powell and Grodal, 2005) represented by cluster organisations. The partners' knowledge-based capabilities, in particular their absorptive capacity, or their capacity to recognise the value of external information, to absorb it, and to commercialise it, are essential for the success of innovation networking (Cohen and Levinthal, 1989).

Conclusions and recommendations

In conclusion, cluster organisation managers in the Visegrad Group countries are actively involved in nurturing and developing research-business cooperation between cluster organisation members. However, their level of involvement varies across respective countries. Cluster organisations serve as multilevel and multifaceted platforms that create ecosystems fostering cooperation between companies and research organisations (including universities). At the initial stage research-business linkages between cluster organisation members are often initiated by cluster organisation management. As the linkages become more mature, cluster organisation management may become less aware of their details, unless it engages e.g. in managing R&D&I projects on its own. The study also diagnosed barriers of research-business cooperation, amongst which the key ones include capacity constraints of R&D&I in small and medium-sized enterprises, the cost of cooperation due to administrative overheads, and the differences in organisation interests and cultures.

Recommendations based on the results of the conducted study were primarily inspired by the unveiled barriers of cooperation between companies and businesses. Most key issues across the Visegrad Group countries originate in the science sector. The differences in the organisation structure of companies and administration

structure in research organisations is a source of negative experiences in all V4 countries, and for that reason addressing this issue should be a top priority. Another key issue in Hungary and Poland – administrative overheads – is also a matter that should be dealt with accordingly, and an open dialogue on this topic should be conducted. In the case of the Czech Republic and Slovakia, the capacity constraints of R&D&I in SMEs as a barrier of cooperation could be potentially diminished in importance if (a) cooperation engaged multiple SMEs and/or (b) the R&D&I potential of small and medium-sized enterprises were improved.

The authors are aware of the limitations of the conducted research, which primarily stem from the number of cluster organisations included in the study and the number of survey respondents. However small this number might seem, the intention of the participants of the project was to analyse the cases of cluster organisations of a certain standing as described in the methodology section of this paper. Despite these shortcomings, the paper's main contributions include (a) providing a comparative analysis of cooperation between business and research in cluster organisations in the Visegrad countries, and (b) exploration and confirmation of the role of cluster organisations in initiating and supporting this type of cooperation. The study sheds new light on the role of cluster organisations, showing how they promote science-business cooperation. The research findings may inspire cluster organisation managers and other actors to create a common innovation ecosystem, or encourage companies to implement joint research projects together with research organisations, which could result in commercialising their research results.

Future research on the topic of business-research cooperation within cluster organisations could take various forms. It may be beneficial to conduct further comparative research focused on the results of business-research cooperation in the context of different industry clusters and different research and education policy regimes. Moreover, the relation between business-research cooperation dynamics and the cluster life cycle could also potentially be an interesting research topic.

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