Key policy mechanisms supporting the University–Industry collaboration in the Danube region: case study of academic HPC centres and SMEs

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Abstract

Purpose – This paper aims to explore the key anchors of the National Innovation System shaping the nature of collaboration between academic high-performance computing centres (academic HPC centres) and small- to medium-sized enterprises (SMEs) working in the automotive and electronics sectors of the Danube region. With two main research questions, it discusses the importance of knowledge transfer and technology transfer for collaboration between University and Industry (U-I collaboration) in three groups of developmentally distinct countries: competitively advanced, competitively intermediate and competitively lagging. As main anchors of the innovation system, stable legal environment, exciting innovation policies and strong R&D funding are recognised.

Design/methodology/approach – A qualitative empirical study in 14 Danube region countries included 92 focus group participants, expert representatives of academic HPC centres and SMEs. The data were audio recorded, transcribed and analysed.

Findings – The findings show the main prerequisites of the framework conditions for efficient U-I collaboration evolve through a goal-oriented National Innovation Policy and developed and functioning legal environment supporting labour market and intellectual property (IP) protection and enforcement. Additionally, skilled people are needed to be able to operate with HPC, where it seems all the countries lack such skilled workforce. In competitively lagging countries, the high levels of brain drain exhibit strong impact to U-I collaboration.

Research limitations/implications – Research into relationships between academic HPC centres and SMEs conducted was qualitative; therefore, limitations in terms of generalisation arise from it. On the other hand, the research is promising in terms of offering the guidance for policy makers who can use the findings when delivering innovation policy mix, adjusted to developmental level of own innovation ecosystem.

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Originality/value – The study is among the pioneering work in U-I collaboration between academic HPC centres and SMEs from automotive and electronics industries in the Danube region. The research addresses the dynamics of collaboration and offers policy implications to strengthen the particular U-I collaboration.

Keywords Innovation, National Innovation System, Technology diffusion, Technology transfer, Knowledge flows, Supercomputing, HPC, University-industry collaboration, Automotive and electronics industries, Danube region

Paper type Research paper

1. Introduction

Collaboration intrigues, especially in innovation studies, where it is well established that the collaboration and knowledge exchange are the drivers of progress. With the rise of the knowledge society, knowledge economy and the importance of the global research networks (Guimón and Paunov, 2022), the processes only sped up, demanding strategic collaborations on all levels. However, one, in particular, remains for us. It is the intrigue of numerous researchers exploring the dynamics of University–Industry collaboration (U-I collaboration). U-I collaboration (from here onwards U-I collaboration) is an intriguing case of two paradigmatically distinct business models (Buehling and Geissler, 2022) that were only recently addressed through the perspectives of Entrepreneurial University or even open innovation (De Bernardi *et al.*, 2020). But most of all U-I collaboration is recently being addressed to as a mean to uplift the "*third mission*" of the universities (Nsanzumuhire and Groot, 2020). Among the factors recognised as game changers, also when addressing the U-I collaboration, there is the rapid development of ICT (Hönigsberg and Dinter, 2019) and its utility in innovation processes and competitiveness (Tarutė and Gatautis, 2014), let alone communication (Camarinha-Matos *et al.*, 2019).

In terms of the desire to re-industrialise the Danube Region countries (Besednjak Valič, 2019), the U-I collaborations are welcomed and looked for, taking into account the need of the Industry to follow the global trend of digital transformation (Guimón and Paunov, 2022) and to move towards Industry 4.0 (Crupi *et al.*, 2020). To keep up with original equipment manufacturers' (OEMs') demands (Hafner and Modic, 2020; Kurpjuweit *et al.*, 2018), small- to medium-sized enterprises (SMEs) need to keep up with new technologies, such as high-performance computing (HPC) or supercomputing. HPC services can be of help (Suklan, 2019).

The present study explores the role institutional framework and actors of the triple helix of the National Innovation System (NIS) play when framing the U-I collaboration. As research shows (Nsanzumuhire and Groot, 2020), a gap in the developing countries with the respect of the U-I collaboration exists. On that note, our research focussed on the dynamics of such collaborations within developmentally distinct groups of Danube region countries. Focus group discussions included triple helix experts and representatives on U-I collaboration within those particular countries. We conducted the research within the scope of the Danube region academic HPC centres representing the University sphere and SMEs working in the automotive industry as suppliers to OEMs as Industry representatives.

Focussing on institutional frameworks surrounding the U-I collaboration, the main research questions deriving from the given situations are the following:

RQ1. What are the key anchors of the institutional forces for establishing effective U-I collaboration for the cases of academic HPC centres and SMEs in the Danube region?

RQ2. What policy mechanisms seem most appropriate to encourage the U-I collaboration among academic HPC centres and SMEs in the Danube region?

To respond to both research questions, we adopted the inductive approach, underpinning the qualitative research process. The analysis of the focus group discussion will deliver responses to the main research questions. In providing the answers, we will rely on a case-based approach.

The authors structured the paper the following way: first, we set the research's main concepts and starting points. Description of data collection follows next, and after that, the data analysis report. The final part of the paper delivers the discussion with conclusions.

2. Institutions, National Innovation Systems and HPC in the context of University–Industry collaboration in the Danube region

2.1 Institutions and key anchors for collaboration

Sociologically, when addressing U-I collaboration, we lean on neo-institutional theory as dominating organisational studies (Alvesson and Spicer, 2019). The presented research defines institutions as formalised, regulative (example legislation) (Alvesson and Spicer, 2019). On the other hand, we describe the institutions working within the legal setting as organisations. Adopting such an approach, we believe a sharper distinction between institutions (codified agreements) and organisations (formalised groups of employees working under established rules) is needed. Having said all this, to understand further the U-I collaboration dynamics, we need to remain aware that both organisations do not operate independently of the social environment. Therefore, the NIS approach is further adopted.

2.2 Innovation systems

With full awareness of different definitions of innovation system as one "*genotype*", we focus on the concept of NIS, as several "*phenotypes*" (Modic and Rončević, 2018) among the for example also: regional innovation system, sectoral innovation system or even corporate innovation system (Granstrand and Holgersson, 2020). Having said that, we follow Freeman (1987) who defined the NIS as a network of institutions interacting, importing, modifying and diffusing new technologies. However, some institutions mentioned earlier act as organisations with established organisational fields (DiMaggio and Powell, 1983). The organisations operating within NIS can be in the public or private sector (Freeman, 1987). Following the definition of NIS, we understand innovation as a sophisticated and complex process in which different elements of the system are linked to each other, enabling the sharing of knowledge and the mutual support for innovation activities (Lundvall, 1992) but especially emerging technologies and innovations (Lundvall, 2007; Nelson, 1993). NIS is composed of the linkages and flow of information among the different actors of the system concerning the generation of ideas and the innovation process (Lundvall, 2007). Other governmental policies address the importance of NIS, and policymakers invest efforts in connecting different actors of the economy (Arranz *et al.*, 2020).

Several attempts (Kuhlmann, 2001) structure the relationships among stakeholders of NIS by demonstrating the complexity of relationships among them. The most interesting is the model by (Warnke *et al.*, 2016). The model focusses on the two main subsystems of NIS: University and Industry. Intermediary organisations interlink both subsystems. The political system and influence shape the subsystems of the demand system, the framework conditions and the existing infrastructure system (Warnke *et al.*, 2016).

Different systemic arrangements, such as configurations of stakeholders and organisations, can deliver similar levels of innovative performance. Research of the European NIS over the last ten years reveals that innovation systems show inherent complexity, which leads to a high level of complementarity among their constituent components and configuration. This result implies that successful innovation policies should be systemic, leaving little flexibility in policy design and scope (Cirillo *et al.*, 2019). However, there are specific strategic competences to be developed at the level of territorial actors (Fric *et al.*, 2023). As substantive knowledge and strategic connections are among the most relevant (ibid), the plan for the future development of NIS suggests adaptation to global trends, adaptation of NIS to country specifics and fitting entrepreneurial innovation into NIS (López-Rubio *et al.*, 2022).

However, in cases of obstructed evolution of the innovation systems, the weaknesses of markets, institutions, organisations and networks are emphasised (Carlsson and Jacobsson, 1997; Jacobsson and Bergek, 2006; Jacobsson and Johnson, 2000; Rotmans *et al.*, 2001; Unruh, 2000). A weakened system structure may lead to co-called system failure, meaning a system fails to develop or does so in a stunted fashion (Carlsson and Jacobsson, 1997). There are several levels of a system failure, while for the present discussion, we focus on system failure concerning structural components (Bergek *et al.*, 2008). To prevent system failure, proper policies need to be elaborated, strategically steered to achieve economic and societal development (Rončević and Besednjak Valič, 2022).

2.3 National Innovation Systems as a triple helix

The model of NIS (Lundvall, 1992) can also be used to explain the creation of socially relevant knowledge. To illustrate the dynamics of socioeconomic relations in knowledge creation processes between the academic, economic and governmental spheres, we will use the triple helix model (Leydesdorff and Etzkowitz, 1998, 2001; Ranga and Etzkowitz, 2013). The triple helix model spotlights a trilateral network of relations between University, Industry and public authorities with the expectation to create a novel knowledge infrastructure. This involves bringing these three subsystems together, each assuming own respective role, and establishing effective organizations at the intermediate level. We place the production and transfer of knowledge at the centre of the concept of the triple spiral as a fundamental issue that converts the three subsystems. The triple helix model also tries to illuminate and explain the dynamics of internal changes in individual social subsystems as well as changes in the relationships between them.

Having said all the above, we describe the above three types of actors within the institutional framework for further conceptualisation and analysis. All three are structured as organisations and operate within the same system, undertaking their roles. Their actions and interaction thus contribute to the innovativeness of the NIS and might, in the same manner, contribute to system failure. The actors are the following: academic HPC centres, SMEs working in the automotive and electronics industries and public authorities.

2.4 Diffusing high-performance computing in the European Union

In cases when regulation obstructs the deployment of particular technologies, promising developmental trajectories may be foreclosed (Martin *et al.*, 2019). However, the law can also provide additional incentives for innovation, leading to the creation of new technologies, products and markets and the discovery of overlooked efficiencies—see also Porter hypothesis (Porter and van der Linde, 1995). Early adopters may enjoy first-mover advantages in export markets. Regulation can foster consumer trust, increasing demand for new technologies (Martin *et al.*, 2019). The countries of the EU have started to recognise the importance of intertwinement of University and Industry (Besednjak Valič *et al.*, 2023) and include this in their innovation policy mix (Modic and Rončević, 2018).

However, the HPC remains costly infrastructure, expensive also to maintain (Sajay and Babu, 2016), and it is the cost that are seen as the major burden for SMEs when deciding to adopt HPC (Botelho Junior and O'Gorman, 2022). Additionally, it is Sakellariou *et al.* (2018) who is focussing on challenges in interplay between Industry 4.0 and HPC, especially in the context of smart manufacturing systems. The authors detect the most common challenges in the interplay between Industry (4.0) and HPC: The first arises from the environment adaption of the HPC as HPCs consumes large amounts of data and resources. As HPC systems become interconnected with manufacturing systems, they will act in line with overall systems performance. And overall systems might have other objectives but time, for example energy consumptions, network traffic etc. following this Gitler *et al.* (2020) explore different regional ecosystems in Latin America to understand the overall regional specifics.

Others studies also approach the non-technical aspects of HPC, see also Botelho Junior and O'Gorman (2022), who outline detect a range of studies focussing on HPC in the context of manufacturing innovation (Kim, 2016). Basili *et al.* (2008) detect common traits in HPC project as lack of targeted HPC training and issues related to code development. Lastly, there is a specific lack of competences detected among the SMEs, especially when it comes to accessing the HPC as it predominantly occurs through the cloud (Lu *et al.*, 2022).

2.5 Innovativeness of the Danube region

The Danube region is a joint name for numerous countries in the Danube basin. Danube river is the second longest European river and runs through a total of 10 countries. The territory of the Danube basin is, in policy terms, covered by the European Union strategy for the Danube region (EUSDR, 2022).

The EUSDR covers the area spreading from the Black Forest in Germany to the Black Sea (Romania, Moldova and partially Ukraine) (Besednjak Valič, 2019). Up to 115m people inhabit the region. The Danube region and the EUSDR cover the following EU member states: Austria, Bulgaria, Croatia, Czech Republic, Germany (regions of Baden-Wurttemberg and Bayern), Hungary, Romania, Slovakia, and Slovenia), Pre-accession countries (Bosnia and Herzegovina, Montenegro and Serbia) and neighbouring countries (Moldova and, since 2022, also whole Ukraine) (Besednjak Valič, 2019).

All the above-listed countries rank very differently according to numerous statistics and reports. We could group them into three groups for further data analysis and interpretations. We did this based on their ranking by adopting the Global Competitiveness Index (Schwab, 2018). The first group was named the group of competitively advanced countries. This group includes the countries: Germany (Baden- Württemberg), Austria, the Czech Republic and Slovenia. The second group was named the group of competitively intermediate countries. The group includes Slovakia, Hungary, Bulgaria and Romania. Lastly, the third group was called the group of competitively lagging countries. It contains countries: Serbia, Croatia, Montenegro, Ukraine, Moldova and Bosnia and Herzegovina.

To sum up, researching institutional aspects of NIS needs to distinguish the difference between institutions and organisations of NIS and should focus on the interactions of two main subsystems of NIS – University and Industry while keeping in mind the distinctive differences between NIS. Adopting a triple helix approach is necessary, especially in developing countries where public authorities' intervention will enable the framework conditions for NIS development. The process is tested further on in the case of three developmentally different groups of Danube region countries. We have researched the particularities of U-I collaboration in the case of collaboration between academic HPC centres and SMEs.

3. Methodology

We analysed the data collected within the InnoHPC (InnoHPC, 2017) project to respond to the proposed research questions. As the project was transnational, the data collection took place in 14 countries of the Danube region, mostly by different performers and with groups gathered on the local availability. The data collection period ranged from May to October 2017. We conducted fourteen focus groups, and Table 1 delivers the number of participants

No.	Group according to global competitiveness index (2018)	Country	No. of participants	Participants profiles
1	*Competitively advanced*	Austria	6	3 industry representatives 2 academic HPC representatives 1 policy maker—national level
2		Czech Republic	6	3 industry representatives 1 academic HPC representatives 2 policy maker—national level
3		Germany (Baden-Württemberg)	7	3 industry representatives 4 academic HPC representatives
4		Slovenia	15	10 industry representatives 3 academic HPC representatives 2 policy makers—national level
5	*Competitively intermediate*	Bulgaria	6	2 industry representatives 2 academic HPC representatives 2 policy makers—national level
6		Hungary	10	6 industry representatives 3 academic HPC representatives 1 policy makers—national level
7		Romania	5	2 industry representatives 1 academic HPC representatives 2 policy makers—national level
8		Slovakia	6	3 industry representatives 1 academic HPC representatives 2 policy makers—national level
9	*Competitively lagging*	Croatia	5	3 industry representatives 2 academic HPC representatives
10		Bosnia and Herzegovina	4	2 industry representatives 1 academic HPC representatives 1 policy maker—local level
11		Moldova	4	1 industry representative 1 academic HPC representative 2 policy makers—national level
12		Montenegro	3	2 industry representatives 1 academic HPC representatives
13		Serbia	10	5 industry representatives 3 academic HPC representatives 2 policy makers—national level
14		Ukraine	5	4 industry representatives 1 academic HPC representatives

Source(s): InnoHPC (2017), own grouping according to Schwab (2018)

Table 1.
Number of expert participants per focus group

for each focus group. Additionally, Table 1 displays the groupings based on Global Competitiveness Index. The data collection for Germany took place in Baden- Württemberg focussing on the dynamics of that particular region. In each of the countries, one expert focus group was conducted, with expert speakers and representatives of the triple helix (Ranga and Etzkowitz, 2013) actors from the fields of academic HPC centres, Industry and policy-making. We invited the expert speakers to the discussion based on their expertise in HPC and technology transfer.

The whole research process (Alase, 2017) followed the interpretative paradigm (Lamut and Macur, 2012; Smith and Shinebourne, 2012). Within the analysis process, the authors also introduced the phenomenological aspect (Miller *et al.*, 2018). Guba and Lincoln (2004) point out that reality is constructed by the individual, so there are different interpretations of the same problem. The individual's interpretation of the problem under study is not only conditioned by their knowledge, experience and values but also depends on the specific historical, cultural and political context (Guba and Lincoln, 2004) of the environment in which the individual operates. By leaning on an interpretative paradigm, authors put emphasis on examining subjective experiences, reflections and understandings and as well as determining what meaning is attached to research topic, from the perspective of the participants included in the study.

The authors adopted a multistage qualitative content analysis approach when analysing and interpreting the data. The data collection and analysis procedure included, first, audio recorded and transcribed data collection. To obtain good transcriptions, the authors ensured the correct meanings and opinions. Second, the transcriptions were organised and arranged into a coding table. The coding table was structured to enable the position of the same question and pertaining response within a single line. Once we arranged and transcribed the data, we conducted the first reading. In the next step, we structured the data according to the two main research questions, based on the key detected topics. The final phase included the open coding of data. Lastly, we created the paradigm model based on the open coding results. The authors contributed equally to safeguarding the process and ensuring the objectivity of the analysis.

4. Results

The interviewees belonging to the group of competitively advanced countries consider the role of public authorities as weak when it comes to using HPC for industrial purposes. National policies do not seem to promote cooperation between the academic HPC centres and Industry. Further on, interviewees of the competitively advanced countries criticise the inadequate national policies in terms of limited budgetary support for U-I collaboration in the field of HPC. Subsequently, the academic HPC centres and Industry identify EU project funding as a viable source of financing for HPC infrastructure. As a result, organisations form international links and cooperation. Interviewees from the group of competitively advanced countries criticise their national strategies for lack of vision on using HPC in R&D and U-I collaboration. However, they also highlight the presence and support of national policies for tuition fee-free public offerings of HPC training/education. The workforce skilled in HPC is crucial as interviewees identify the numerous potentials of the professional labour force. According to the interviewees, the low level of HPC skills is present even among the experts.

In order to mitigate the issues related to skills to use the HPC, the respondents detect potential in organisation of non-formal training related to the use of HPC technology. Such activity is necessary, as specific HPC-related knowledge is deficient. Both sectors face this problem—University and Industry. The interviewees of the competitively intermediate countries highlight the supportive role of the public and intermediary organisations for HPC accessibility as opposed to their counterparts from advanced countries. Public organisations provide (public) financing for HPC infrastructure and also promote cooperation between the academic HPC centres and Industry through national calls and tenders. Such type of cooperation is also encouraged by EU-funded projects. At the same time, the interviewees mention the lack of financial support from the EU. The reason for this is the industry's struggle with the administrative requirements of managing EU project documentation. Another reason for the struggle is the slowness of EU funding processes.

The strong links between University and Industry are recognised within the technology transfer offices (TTOs) services by interviewees of the competitively intermediate countries. TTOs have the potential to serve as promotors of cooperation between the academic HPC centres and industry, according to the interviewees. Interviewees agree such an approach is crucial as academic demands in competitively intermediate countries do not necessarily value the applicative research and collaboration with the industry as much as basic research.

National innovation strategies usually define the HPC as a research infrastructure and one of the key enabling technologies for innovation. Based on the opinions of the interviewees, the lack of national strategies reveals itself in weak support of industrial R&D. In industrial R&D, the experts do not recognise the HPC as a priority technology. The interviewees expressed their critique of the national innovation policies as they noted the lack of vision and goals for proper positioning the HPC technology within the industry. Apart from that, the emerging industry sectors seem to be able to establish close links between clusters of potential beneficiaries of HPC infrastructure and technology. Based on the interviewees' opinion, those emerging industry sectors do not provide support for the use of HPCs outside the established clusters. Consequently, according to interviewees, competitively intermediate countries do not exploit the potential of clusters when disseminating both innovation and knowledge linked to HPC technologies.

Public authorities of the group of competitively lagging countries express the rudimentary willingness to improve and transfer of HPC technologies. Interviewees recognise the readiness of public authorities to change legal frameworks towards supporting the use of existing HPC infrastructure. Despite the declarative supportive role of public authorities, the interviewees note that the public authorities themselves act as a critical obstacle to the exploitation of HPC technologies. Public authorities do not provide sufficient financial support in funding R&D. Moreover; the interviewees note that the public authorities do not undertake investments in HPC infrastructure. According to the interviewees, public authorities expect industry initiatives to create and support the R&D and HPC technology clusters. Based on the responses from the interviewees, in the competitively lagging countries, there is a lack of mutual understanding for HPC-related R&D within different sectors. The attitudes of public authorities and the lack of knowledge, according to interviewees, reflect in the absence of strategic documents. The interviewees also note the absence of concrete strategic measures to overcome the status quo.

Focussing on the proposed RQ1, the following response is below:

RQ1. What are the key anchors of the institutional forces for establishing effective U-I collaboration for the cases of academic HPC centres and SMEs in the Danube region?

We presented the key anchors in Table 2. As key anchors for the institutional forces, we outline the technology transfer and knowledge transfer, both depending on the levels of collaboration potentials and collaboration itself. For this purpose, stable legal environment, existing innovation policies and strong R&D funding are recognised as anchors for establishment of U-I collaborations.

The U-I collaboration in the field of HPC offers an opportunity. This opportunity, however, depends on the ability to adopt HPC as HPC is costly and skills demanding infrastructure. Both setbacks are problematic for economically less developed countries experiencing

Key themes	Institutional forces for a collaboration	Policy mechanisms
Information flow between organisations	- Opportunities from academic HPC centres - Promotion of HPC from academic HPC centres - Low awareness of benefits from the side of the Industry	- Public authorities as responsible for a systematic system for the transmission of information
Institutional cooperation	- U-I collaboration is perceived as weak - Poor knowledge transfer, low applicability to Industry - Public authorities ensure free HPC training	- Need to address the development and teaching of HPC competencies systematically - Countries with strong industrial organisations do not require assistance from the public authorities
Knowledge creation in HEI and RI	- Specific cases of high HPC level knowledge exist, especially among younger researchers - Academic HPC centres support cross-sectoral cooperation and knowledge transfer	- Support the development of new study programmes tailored more according to the HPC needs of the industrial sphere
Knowledge transfer, HPC training	- Positive attitudes towards creativity, entrepreneurship and new technologies - Industry is focussed on ICT advancements and innovation - Cooperation between academic HPC centres and Industry is seen as positive	- Senior researchers in some intermediary countries, particularly lagging countries, are not seen as competent to use and teach HPC. - The reform of academic programmes is required
Ability to use HPC	- The Industry obtained the ability and skill to use HPC in advanced countries - Industry in advanced countries owns HPC research centres. Such ownership is an obstacle to collaboration in the academic HPC sphere - Results in the exclusivity of knowledge - Industry fears data disclosure and worries about data protection in the external HPC infrastructure - Industry in competitively intermediate and competitively lagging countries frequently is not HPC ready – neither in awareness, type of products, nor skills	- In intermediate and competitively lagging countries, the industries rely upon policy support when developing and using the HPC technology - The competitively lagging countries face shadow economy and tax evasion; the level of socio-economic development is the main obstacle to HPC utilisation in Industry
HPC setbacks for SMEs	- HPC readiness of the SMEs is low for reasons like; low awareness of the usefulness of HPC, lack of adequately trained human resources, high cost of licensed software, and rental of HPC infrastructure - HPC is predominantly available through EU funding. EU-funded HPC is not open to the private sector - EU projects support international networks	- In competitively intermediate and lagging countries, the academic HPC centres focus on theoretical research - Slow transfer of HPC knowledge to Industry - EU projects demand extensive administrative work. Due to the complexity of project documentation, SMEs do not desire to consider EU project funding
Transnational collaboration	- Industrial R&D needs in competitively intermediate, and lagging countries are addressed abroad	- Weak U-I collaboration in general in competitively intermediate and lagging countries

(*continued*)

Table 2.
Key themes defining institutional forces for collaboration and policy mechanisms

Key themes	Institutional forces for a collaboration	Policy mechanisms
The competitive advantage of HPC usage	- Competitively advanced and some competitively intermediary countries demonstrate collaboration between academic HPC centres to ensure competitive advantage	- The usage of HPC varies across the Danube region - Presence of clustering in automotive and electronics sectors
National innovation policy	- Existing policies support collaboration - Need for working legal environment - Public authorities are seen as hinderers of collaboration - National innovation policy needs a vision. The lack of clear long-term goals is a weakness. The non-critical best practices imported from other cultural settings are de-motivating in competitively intermediate countries - Policies supporting innovation agents who engage in clusters and networks exist in advanced countries - Slow implementation of policies, too bureaucratic approach - Unstable national and EU funding results in low investment/funding in science - Without national support, academia in competitively lagging countries creates transnational networks due to self-initiative	- In competitively intermediate and lagging countries, provision of funding for SMEs - Request the training for HPC to be free and open - Policy needs to ensure financial support for HPC (and related IPR) and promote innovation - Too much focus on solving unemployment problems *per se* - Too slow recognition of R&D profitability in competitively intermediate and lagging countries
Role of public authorities	- Public organisations are considered an obstacle to the diffusion of technology - Lack of interest in HPC in the competitively intermediate and lagging Danube region countries - Solely declarative support to HPC application - Lack of support for U-I collaboration - Lack of support towards forming networks, especially between University and Industry, as public-private partnerships are considered fraud in some competitively intermediate countries - In competitively advanced countries, the critical decision maker in national networks is in academia, while in competitively intermediate countries, the crucial actor in the networks is Industry	- Policy that enables stable financing of HPC infrastructure is considered sufficient - Lack of legislation, including IPR protection and enforcement (especially in lagging countries) - Weak or absent Internet infrastructure in some countries - Lack of long-term vision regarding innovation and short-term and long-term goals - Slow and bureaucratic policy implementation - Lack of recognition of HPC's effectiveness in the diffusion of technology

Table 2.

(*continued*)

Key themes	Institutional forces for a collaboration	Policy mechanisms
Issue of brain drain and migration	- In competitively advanced countries, the talents are attracted by the high quality of life and high quality of academically exciting research groups, professors with HPC competencies, and established U-I collaboration through study programs and HPC usage during the study - Competitively intermediate countries can also attract talented people but have difficulties retaining them - The competitively lagging Danube region countries cannot attract or retain talented individuals from other countries, as they cannot stem their brain drain	- Competitively intermediate countries are incapable of retaining talented people due to labour market issues (legislation, taxation, and incompatibility of wages with the complexity of work) - Competitively lagging countries note underdeveloped Industry, inadequate political system and labour market together with underfinanced and low-quality academic sphere - EU migration policy and globalisation support brain drain from competitively lagging countries

Source(s): Own research results interpretation

Table 2.

problems of brain drain. The ability to use HPC is prerogative for technology transfer and knowledge transfer processes.

Lastly, in competitively advanced countries accessibility to HPC capabilities lies often within organisations, where, HPC technology helps achieving organisation's strategic goals. In contrast, in competitively intermediate and competitively lagging countries, the case HPC technology is primarily introduced via higher education institutions (HEI). Further communication and cooperation with industrial actors are hindered because of the lack of competent professionals, but also due to intellectual property rights (IPR) concerns.

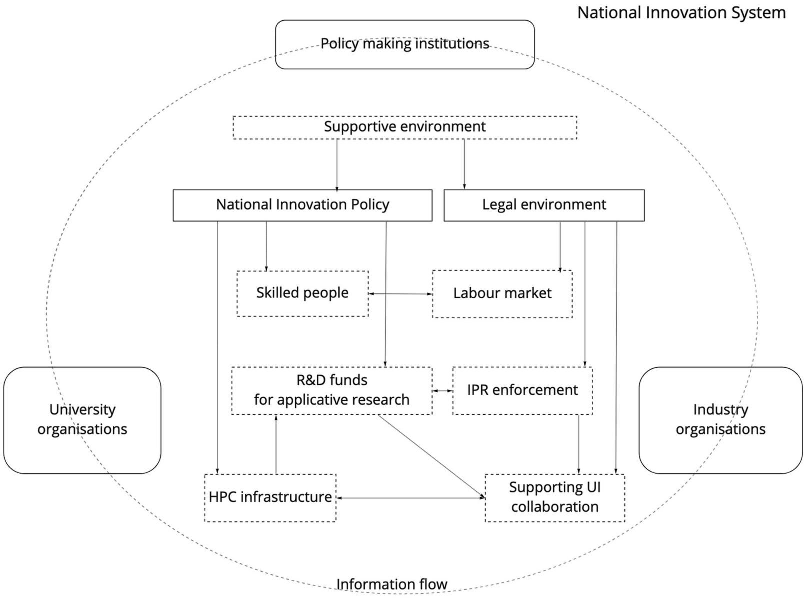
RQ2. What policy mechanisms seem most appropriate to encourage the U-I collaboration among academic HPC centres and SMEs in the Danube region?

Regarding policy mechanisms considered appropriate to address the given situations, Table 2 reveals issues on several levels. First, the public authorities must ensure the proper information flow among all triple helix actors. Second, the policies must support the demand for a skilled workforce, supporting curricula adjustments. Based on that, the policies should be set in a way to promote HPC competencies, not only among junior but also among senior staff. A stable legal environment must support for U-I collaboration and the establishment of competitive labour markets. The interviewees particularly emphasised the need to ensure the funds invested in R&D return as profits. Supported U-I applicable research can secure such returns in profits. The interviewees expect a systematic solution for providing and funding HPC infrastructure.

The below paradigm model was developed based on the analyses and responses to both research questions. The functioning NIS can play a central role through sufficient information flow among all system stakeholders. Second, a competitive National Innovation Policy that fosters technological readiness and people skills is essential. Also, the National Innovation Policy should support R&D investment to be turned into profitable products. Third, the legal environment must provide IPR enforcement and competitive labour market conditions (see Figure 1).

5. Discussion and conclusions

In a time of fierce global competition and increased transition towards new business models for numerous sectors and organisations, the U-I collaboration facilitated by public authorities



Source(s): Besednjak Valič (2022)

Figure 1.
Anchoring NIS for HPC diffusion in Danube region—paradigm model

seems to remain at the heart of innovation processes. Enabling more vital collaboration is a task for numerous prosperous OECD countries (Haeussler and Colyvas, 2011). To facilitate the paradigmatic shift in research orientation, University and Industry need specific framework conditions for the collaboration to realise. Research results show that the most critical institutional anchors are two—efficient and straightforward National Innovation Strategy and a functioning legal environment. The National Innovation Strategy must focus on supporting the skilled workforce, implementing and maintaining HPC technology, and actively supporting relevant R&D research. In this context, a need for multilevel responsibility for innovation policy (as also in Modic and Rončević, 2018) is required. The practical legal environment must ensure a stimulating labour market that attracts and attain talented people and must provide the protection and enforcement of IP rights. The same conclusions can be confirmed by Viale and Campodall'Orto (2002) who are aware, together with Mali (2009), based on such legislation, that knowledge transfer is either supported or hindered. Additionally, National Innovation Strategy must support U-I collaborations in terms of equal valuation of basic and applicative research along with labour legislation enabling easier transfers of researchers from University to Industry and vice versa (Viale and Campodall'Orto, 2002).

Concerning cases of NIS failure, the results of our presented research confirmed the findings of (Bergek *et al.*, 2008). The establishment of efficient U-I collaboration between academic HPC centres and SMEs of automotive and electronics industries in the Danube region is hindered by (a) infrastructural failures, such as lack of HPC infrastructure; (b) institutional failures, such as corruption and non-functioning legislation; and (c) capabilities failures, such as lack of skilled workforce and collaboration. The findings go in line with detected barriers to U-I collaboration (Nsanzumuhire and Groot, 2020).

For the presented case of three groups of countries of the Danube region, we met two distinctions worth further exploring: (a) developmentally differentiated countries seem to have different needs when supporting U-I collaboration. Economically less developed countries rely more on public authorities and their support in the U-I collaboration endeavours. (b) In competitively lagging countries of the Danube region, a distinct pattern of rigidity in considering collaborations between academic HPC centres and SMEs was noted, especially from the side of academia. The role of mental frameworks, especially considering national/cultural characteristics in U-I collaborations, could be more important than previously considered and can be subject to further explorations of the collaboration dynamics. Additionally, following the conceptualisations of ideal types of competence model for smart territorial development (Fric *et al.*, 2023), particularly tailored policy mix can be formulated for each of the specific regional contexts.

Apart from many insightful findings, the authors are aware of the study's main limitations—results are limited to the case studies of relationships between academic HPC centres and SMEs working in automotive or electronics industries in the Danube region. However, the results still can serve as the cases of deep knowledge and guidance for future work. Apart from the sample size, another major limitation of the study is in the age of collected data. Since 2017, many world-changing events took place; however, the field of U-I collaboration within the scope of key enabling technologies (HPC included) has not changed much let alone change the main findings of the present paper.

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