Working Paper Series

#2021-026

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Published 27 May 2021

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UNU-MERIT Working Papers
ISSN 1871-9872

Maastricht Economic and social Research Institute on Innovation and Technology
UNU-MERIT

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Knowledge Transfer Activities and Conditions for Impact in Bulgarian Public Research Institutions:

A Survey-based Diagnostic *

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*An extended version of this study was published as "Enhancing the Contribution of Bulgaria's Public Research to Innovation: A Survey-based Diagnostic". Washington, D.C. World Bank Group.

Acknowledgments: This research and an earlier version of this study benefited from the research assistance and contributions from Teodora Georgieva and Lyubomira Dimitrova. We are thankful to Gabriel Goddard and Smita Kuriaskose for insightful comments to the first version of this study. This work was supported by the World Bank, Europe and Central Asia, Finance and Competitiveness Division.

Abstract

This paper analyses the state of progress in knowledge and technology transfer activities in Bulgarian public research organisations. It explores the nature and development of research competences, engagement in research collaboration, and technology transfer activities at public research institutions and aims to identify the factors that enable or constrain these activities. The results are based on a survey of public researchers, public research organisations (PROs), and university technology transfer offices (TTOs) in Bulgaria. Our findings show important gaps in institutional governance (linking research with industry demand), misalignments in academic incentives, and constraints related to lack of funding and capacity. Our findings also highlight the vital importance of mobility of researchers as catalyser of collaborative research and technology transfer linkages in both types of institutions and provides proposals for action in terms of policy and institutional reform to improve the performance and impact of public research.

Key Words: knowledge transfer, technology transfer, industry-science linkages, public research organisations, Bulgaria.

JEL Classification: O31, O33, O38, I23

Introduction

Despite strong economic growth over the last three decades, Bulgaria has not transitioned from a factor-driven economy to an innovation-driven economy. While the economy and income levels grew rapidly during the period following the transition from communism, Bulgaria's innovative outputs plunged post-1990 due to an erosion of the country's technological and scientific competences (World Bank, 2013). Although Bulgaria's research capacity has experienced a slow recovery, it still lags most European countries in both research investment and innovation capacity (total investment relative to Gross Domestic Product) and scientific performance -i.e. publications per researcher. One of the primary areas deserving attention is public research.

As Bulgaria increases funding for Research and Development (R&D onwards) to meet its 2030 targets for research funding, these new investments are expected to increase technological and scientific performance and address major national innovation needs in both industry and society. The pace and effectiveness through which research outputs from public science and technology (S&T) institutions are transformed into new or better products and processes has a substantial impact on the contribution of those public investments to economic development (Correa and Zuniga, 2013). The economic impact of university research has come under increased public scrutiny as policy makers debate the future of university funding models and the metrics and evaluation methods that should be used to assess the impact of science and publicly-funded research (e.g. Jonkers and Zacharewicz, 2016; Arundel and Wunsch-Vincent, 2021; Coombs and Meijer, 2020). In parallel, stringency in government accountability, combined with increasingly tighter federal budgets, have reinforced the need for universities and PROs to report how their research activities translate into economic and development benefits for society (Hicks 2012; Cruz-Castro and Sanz-Menendez, 2018).

To respond to these exigencies, many developed countries have engaged in policy and regulatory reforms aimed at modernising the policy and regulatory frameworks governing science and public research institutions to improve the impact of research and the transfer of resulting technologies to industry (OECD; 2013, Wunsch-Vincent and Zuniga, 2012). These reforms include revisions to existing legal frameworks and organic laws governing public institutions and the revision or creation of new policy frameworks and rules concerning the creation and commercialisation of intellectual property (IP) resulting from publicly funded research. Another area of reform is the institutional autonomy of public institutions and providing them with the legal capacity to engage in commercialisation activities. These institutional and regulatory reforms seek to improve the context conditions required for public S&T institutions to deploy their technology transfer mission (or "third mission" in the case of universities) more effectively and thereby increase the impact of public research to innovation and development. These trends take part of a broader modernisation process taking place in public research organisations which seeks to promote a more open and collaborative mindset, improve accountability and resource allocation, and more results-oriented management culture.

This paper analyses the state of progress in knowledge and technology transfer activities in Bulgarian public research organisations. It explores the nature and development of research competences, engagement in research collaboration, and technology transfer activities at public research institutions and aims to identify the factors that enable or constrain these activities. Our main questions are: Are the current governance and regulatory frameworks conducive to technology transfer and industry-science collaboration? Are academic incentives in place and in line with international practices and with technology transfer goals? Are external stakeholders (e.g., industry, government, etc.) considered in research strategies and priorities in PROs and HEIs? What are the barriers that keep these public institutions from contributing to innovation and development?

We analyse these questions with a new survey methodology adapted to PROs and TTOs, as well as a separate survey for public sector researchers. We build our analysis based on lessons from the academic literature on the impact of public research institutions (OECD 2010; Correa and Zuniga, 2013; Cirera, Kuriaskose and Zuniga, 2021), the modernisation of PROs (Hicks 2012; Cruz-Castro and Sanz-Menendez, 2018; Intarakumnerd and Goto, 2018) and the transformation of universities into more entrepreneurial institutions (Siegel *et al.,* 2004; Laredo and Mustar 2004; OECD, 2003; Bercovitz and Feldman, 2008; Tijssen, Lamers, and Yegros, 2017), different lessons from international experiences regarding the strengthening and modernisation of public research institutions and universities (European Commission, 2009; Jonkers and Zacharewicz, 2016; Zuniga, 2020), and the different institutional strategies to enhance the impact of public research (Jensen *et al.,* 2001; Chang *et al.,* 2009).

Two surveys were implemented during the first quarter of 2020: one in-person survey of administrators from a sample of public research organisations (PROs) and higher education institution (HEI) TTOs; and an online survey of over 4,000 public sector researchers in Bulgaria. Our findings show important gaps in institutional governance (linking research with industry demand), misalignments in academic incentives, and constraints related to lack of funding and capacity. Our findings also highlight the vital importance of mobility of researchers as catalyser of collaborative research and technology transfer linkages in both types of institutions.

The contribution of this work is twofold. It is the first attempt to examine and measure the extent of progress in industry-science collaboration and technology transfer activities in Bulgarian public research institutions. Moreover, we intend to provide a more comprehensive analysis by looking at the different institutional and policy factors shaping this development. Unlike most of previous research, this study makes the effort to consider the developing context of the Bulgarian research system -not only in terms of research capacity but also in terms of institutional development and governance settings (i.e. involvement of industry in governance and strategy definition) and how these help explain differences in technology transfer performance and industry-research collaboration across institutions. These factors are essential for the understanding of institutional transformation required to enhance the impact of public research in developing public research systems and technologically-lagging countries.

The paper is organised in four sections. The first part of this report reviews the general conditions of public sector R&D in Bulgaria in terms of context, policy frameworks for Science and Technology (S&T), and scientific performance. The second section describes the survey and key questions addressed, add the methodology, while the third section briefly reviews the academic literature that helped designed this questionnaire. Section fourth presents the survey findings. The paper concludes with proposals for action in terms of policy and institutional reform to improve the performance and impact of public research.

1. The Bulgarian Public Research System: The Context and Challenges

Public research institutions in Bulgaria face important challenges in improving the quality and relevance of their research. Public investments in R&D are low compared to peer economies (e.g. Czech Republic, Croatia, Poland, Romania, Slovakia, and Turkey) and public institutions suffer from a lack of stable funding and resources. Gross domestic expenditure on R&D (GERD) as a percentage of R&D has been trending down since 2015, dropping to 0.7 percent in 2018, well below the country's 2020 target of 1.5 percent of GDP and its new 2030 target of three percent. Further, the Bulgarian public sector plays a smaller role both in funding and performing R&D relative to peers[2]. Bulgaria reports the lowest share of GERD financed by the national government among

[2] Bulgaria's peers, for the purposes of this article, refers to the Czech Republic, Croatia, Germany, Greece, Poland,

peers, and the public sector (higher education and government) performs a lower share of GERD than found in peer countries.

The low R&D contribution and poor performance of the public and higher education sectors are due to several issues, the largest of which is a lack of funding. Bulgarian research institutions are under-funded compared to peer institutions in Europe. The absence of lasting multiannual commitments for the support of scientific research has been cited as one of the main reasons for the deterioration of science and scientific performance in Bulgaria, and improving financial commitments are one of the focus areas of the current National Strategy for the Development of Scientific Research, 2017-2030. Research funding from nationally financed research grant programs (as opposed to EU-funded programs) is very low and has been relatively static since 2014.[3]

Another structural factor in the poor research performance is the fragmentation of research capabilities across many small institutions in different areas of specialisation, which results in a high dispersion of competences and insufficient specialisation. There is a lack of critical mass of research talent necessary to make an impact and achieve economies of scope and scale. This is, in part, due to the continuous exodus of research and technology talents in Bulgaria, which stems from low salaries and a poor career structure in the public research sector (European Commission, 2015; World Bank, 2013). The recruitment of new scientists is therefore a major challenge.

In terms of research outputs, Bulgaria lags behind most of its peers in both quantity and quality of research outputs. Research outputs, in terms of scientific publications and intellectual property (IP) are lower than in most peers and tend to have little impact on the international scientific community, while commercialisation outcomes (licenses and startups) from public research are extremely limited. Only a small number of Bulgaria's PROs conduct research that meets international standards (World Bank, 2013; Scimago, 2020), and beyond the Bulgarian Academy of Sciences and a few high performing universities in Sofia, there are very few national institutions that meaningfully contribute to the scientific literature. Furthermore, Bulgaria's publications tend to be less cited and less impactful that those of its peers. Bulgaria ranked last among its peers in

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Romania, Slovakia, and the EU 27 average.

[3] The total research grant allocations from the National Science Fund mounted €12 million (or less) annually in total from 2014 to 2018, before increasing slightly to €15.6 million in 2019.

scientific publications among the top 10 percent of most cited publications worldwide as a percentage of total publications in the country in 2019.[4]

Given these vulnerabilities, the impact of public research institutions in terms of knowledge and technology transfer remains a major challenge. Previous studies on the Bulgarian knowledge transfer framework have identified several obstacles to technology transfer – particularly a lack of funding, fragmented research base, and insufficient policy incentives for both researchers and institutions. A 2015 peer review conducted by the European Commission found that public research institutions suffer from a lack of professional management of research and knowledge transfer; a lack of policies that encourage IP disclosure, IP monetisation, and public-private collaboration; and a lack of stable funding and resources for existing TTOs. It also found that knowledge transfer is not part of the mission and core strategy of public universities (European Commission, 2015). A 2019 WIPO assessment of knowledge transfer activities from public research organisations also stressed several important handicaps that limit the impact of public research in Bulgarian institutions. This study found that public institutions need stronger and more standardised intellectual property rights management, better legal and organisational infrastructure, as well as improved staff and resources for technology transfer activities (Spacic *et al.,* 2019).

2. The Survey: Enabling Factors and Policy Drivers

This study aims to capture the extent to which Bulgarian public research institutions (HEIs and PROs) transfer knowledge and technology to industry (and to other innovation actors). Identifying the returns on public R&D investments requires the recognition of the different channels through which research impacts economic development and innovation, including particular focus on the factors that enable or constrain industry-science collaboration and knowledge transfer (Correa and Zuniga, 2013; Aridi and Cowey, 2018). There are multiple ways in which research achieves impact and creates value (Salter and Martin, 2001) and we intend to capture this variety of connections and knowledge transfer impact in our analysis and survey.

Technology transfer from public research organisations can be defined as the movement of know-how, skills (people), technical knowledge, methods, or technology from one organisational setting to another (Roessner *et al.,* 2010; see also Bercovitz and Feldman, 2005; Siegel *et al.,*

[4] Bulgaria and Romania had the lowest share of publications that were cited from 2013-2018, with 46 percent of all publications going uncited during that timeframe (Scimago, 2020).

2003). The literature shows that technology transfer occurs both formally and informally, and recipients can be firms or governmental institutions as well as society itself in a more direct way (e.g. producers, cities/regional governments, civil associations, etc.). The relative importance of such channels varies across science fields and industry sectors (i.e., Thursby and Kem, 2002; Bekkers and Bodas Freitas, 2008; Boardman *et al.,* 2009).

Within the formal ways of technology transfer, collaboration with industry can take different shapes: R&D contracting and consultancy services, the hiring of new graduates and post-graduates, R&D collaboration, joint training programs (e.g. industrial PhD in industry), the (sharing of) equipment and instrumentation, bilateral flows of personnel (e.g. secondment of academic researchers in industry, R&D consortiums and joint research centers, among others).

A narrower, more formal definition refers to technology commercialisation—also known as research commercialisation. This concerns the valorisation of research and intellectual assets by industry and is a sub-set of technology transfer practices – e.g., within the "formal" channels of technology transfer. It implies the selling, licensing of, or purchasing of new technologies (including intellectual property rights and know-how, research tools and materials, etc.), contracting of technology services and related-knowledge, and spinoff creation, including licensing to startups (external to research institutions). Industry and society also receive new ideas from science through informal means such as publications (which are available through scientific databases), personal contacts, and information disseminated at meeting and conferences and networking. Informal channels are particularly important to firms and represent knowledge-spillovers or externalities from research, which have been proven to be shaped by geographical (and technological) proximity (Adams *et al.,* 2000; Cohen *et al.,* 2002).

With the aid of a new survey methodology, we asked institutions and researchers about the number of knowledge and technology transfer activities (i.e. number of contracts or projects in which they were involved), they have engaged in the previous year and in total over the course of their careers. We consider ***knowledge transfer activities*** the following interaction channels: involvement of researchers in the provision of training and educational services (to or jointly with public or private organisations), joint research (with public or private organisations); participation in PhD projects jointly conceived with or conducted in industry, and human capital exchanges (mobility of researchers´ through sabbaticals, industry secondments, or involvement in startups). Within these categories, industry-science collaboration in research is a critical channel to leverage capabilities from public research for industry innovation and offers mutual benefits for both participants. For PROs and universities, benefits include leveraging funding for their research agendas, and identifying new ideas for applied research. For firms, research collaboration can help develop new technological competences thereby increasing innovation performance.

Under the category of ***technology transfer,*** we include the following activities: participation in the provision of technology services, extension services (technology transfer contracts), technical assistance, R&D contracting, R&D collaboration, licensing or selling of IP, or involvement in the creation of startups or academic spinoffs.

Following the literature, our survey questionnaire is organised around three key groups of enabling policy and institutional factors that are expected to influence institutions' ability and motivation to engage in knowledge and technology transfer activities with industry (Correa and Zuniga, 2013; OECD, 2018; Cirera *et al.,* 2020). In a nutshell, these enabling factors can be summarised as follows:

- *Research competences and relevance of research*: These factors include research skills and having a minimum scale in human capital to achieve economies of scale and specialisation see (Blumenthal *et al.,* 1996; Thursby and Kemp, 2002); the quality of research and its relevance to development needs, and more generally, its connection with industry and society (Jensen *et al.,* 2003; O'Shea *et al.,* 2005). Differences across scientific and technology fiends has also been acknowledged in the study and evaluation of knowledge transfer impact from public S&T organisations (Thursby and Kem, 2002; Bekkers and Bodas Freitas, 2008; Boardman et al, 2009).

- *Governance and External Stakeholder Involvement*: These factors relate to the level of institutional autonomy (i.e., Cruz-Castro and Sanz-Menendez, 2018; OECD, 2018) and *governance* structures (i.e. inclusion of industry and societal actors in strategic boards), which are mechanisms that shape the embracement of a more impact-oriented culture and innovation engagement in public S&T institutions (Intarakumnerd and Goto, 2018).

- *Technology transfer policies and regulatory frameworks*: These factors include the set of rules and regulatory frameworks (incentives) for institutions and researchers to engage in collaboration and technology transfer, and funding and specialised resources for technology transfer, such as technology management skills and IP expertise, and supportive intermediation structures such as Technology Transfer Organisations or TTOs (Debackere and Veugeleres, 2005; Jensen *et al.,* 2003; Siegel *et al.,* 2004).

- *Academic Incentives and Regulatory Frameworks shaping Industry-Science Interactions.* Both the international experience and research underscore the importance of providing incentives to those who participate and manage the technology transfer process (Thursby and Thursby, 2004; Litan *et al.,* 2007; Siegel *et al.,* 2007; Debackere and Veugelers, 2005; Muscio *et al.,* 2017). Within these, the provision of financial incentives (i.e., equity participation in spinoffs and royalty sharing) have been found helpful, especially in terms of technology commercialisation and spinoff activity (i.e., Baldini *et al.,* 2006; Muscio *et al.,* 2017). Non-pecuniary incentives -such as academic recognition, awards and public recognition, and mobility incentives- are also key and in many cases- these have been found more important than financial ones (Göektepe and Mahagaonkar, 2008; Baldini *et al.*, 2007).

We further discuss the key messages from the literature at the start of each thematic (survey component) when report our survey results. Following these key insights from research, the last section of our questionnaire refers to obstacles to knowledge and technology transfer activities. We asked institutions and researchers to declare the level of importance of a large set of policy and cultural factors including institutional, regulatory, financial. and cultural barriers for developing collaborative and technology transfer linkages with external innovation actors, distinguishing private and governmental organisations. We report these results from the perspective of both public institutions and researchers at the end of the next section.

2.1 Target population and Implementation

The public research sector in Bulgaria comprises public higher (or tertiary) educational institutions; the Bulgarian Academy of Sciences (BAS); the Agricultural Academy (AA); and a small set of research institutes and hospitals under different sectoral ministries or agencies. Of the 51 higher education institutions (HEIs) in the country, 37 have STEM-related programs and degrees and 12 have university research centers. There are also 91 PROs in Bulgaria. The largest research-performing institutions in Bulgaria are the BAS institutes – a public-funded autonomous body overseen by the Ministry of Education and Science comprising 50 independent institutes, including

36 institutes in STEM fields. It is followed by several Bulgarian universities that are based in the Sofia capital region (e.g. Sofia University and Technical University of Sofia). The second leading PRO is the Bulgarian Agriculture Academy (AA), a public research organisation managed by the Ministry of Agriculture, Food, and Forestry.

This study uses two surveys designed to measure Bulgarian HEIs and PROs knowledge and technology transfer and the factors that influence these activities: 1) an online survey of active public sector researchers in science, technology, engineering, and mathematics, conducted from February to April 2020; and 2) in-person surveys of administrators from Bulgarian PROs and university TTOs. A total of 21 public research institutions were interviewed, including 14 PROs and seven university TTOs, with interviews taking place between February and April 2020. PROs and university TTOs were selected for interviews based on several criteria to cover the breadth of the Bulgarian public research system, including type of research institutions (PRO or HEI); affiliation (BAS, AA, or other), technical field, number of employees and location. The sample of public sector researchers was drawn from the website of the National Center for Information and Documentation (NCID), which maintains an online register of public sector research staff. Academic fields were identified using the ISCED-F 2013 classification[5] provided by UNESCO, which identified 4,260 researchers[6]; 739 completed responses were received (Table 1).

3. Results

3.1 Research Outputs and Technology Transfer Activities

We first analyse the research capacity and performance of Bulgarian public research institutions. Public sector research outputs, in the form of publications and patents, are largely aimed at addressing accreditation requirements, rather than the pursuit of impactful research. While some knowledge exchange activities are relatively common, such as research collaboration with government and industry, long term staff exchanges with industry (e.g., sabbaticals and

[5] ISCED-F 2013 is an international classification developed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) to facilitate comparisons of education statistics and indicators across countries based on uniform and internationally agreed definitions.

[6] The selected fields were: Natural sciences, mathematics, and statistics (ISCED-F 2013 05, excluding 0524 Statistics); Information and communication technologies (ISCED-F 2013 06); Engineering, manufacturing, and construction (ISCED-F 2013 07); Agriculture, forestry, fisheries, and veterinary (ISCED-F 2013 08); and Health and welfare (ISCED-F 2013 09, excluding 092 welfare).

secondments) are rare among surveyed researchers. Researchers in engineering fields are more active in knowledge exchange activities than other disciplines, but all fields show very low levels of commercialisation outcomes (licenses and spinoffs)

Scientific publications are the most common type of research output of Bulgarian public researchers, with 76 percent of surveyed researchers producing one or more publications from 2018 to 2019, while only 1.6 percent were granted an international patent, and 7.8 percent registered a utility model over the same period (Table 1). As detailed in Section 1, Bulgarian publications tend to be less impactful than those produced in peer countries, and public sector publication and patent activity is largely oriented to addressing accreditation requirements and meeting career development milestones, rather than the pursuit of impactful research or the practical implementation of research results by the private sector.

Table 1: Research outputs of surveyed public researchers, 2018-2019

	Average per researcher	Share of researchers with n>0
Scientific publications in international peer-reviewed journal	44	76.0%
Domestic patents granted	0.7	4.5%
International patents granted	0.2	1.6%
Number of utility models	1.6	7.8%

Source: Authors' calculations | Note: Responses are weighted by distribution of researchers by academic field.

Public researcher career development indicators place equal weight on utility models and patents and do not differentiate between domestic and international patents. Because utility models are less expensive, faster, and easier to obtain, public researchers have increasingly turned to protection through utility models. The widespread lack resources for IPR activities means funding is typically not available for patenting under international patent regimes, which has resulted in the low international patent outputs reported by respondents.

The most common form of collaborative research undertaken by public researchers are collaborative R&D projects with industry: 27.8 percent of surveyed researchers worked on a collaborative project with industry in 2019 and 42 percent have worked on such a project over the course of their career (Table 3). Contract research to companies (R&D services commissioned by industry through a contract) and collaborative research projects with other government agencies are also common forms of collaboration, with about one in five researchers engaged in contract research with firms in 2019, and around 13 percent taking part of contract research with governmental agencies. However, technical assistance services to firms (such as engineering, design, and quality testing services) and technology extension services (assistance in the transfer and adoption of new technologies) are less common activities, with only 16 percent and 11 percent of surveyed researchers participating in these activities in 2019, respectively (Table 2). These advisory services are important forms of knowledge transfer of public sector expertise to small businesses and are particularly important in the Bulgarian context, where the private sector lags EU peers in labour productivity, firm digitisation, and the adoption of new technologies.

Table 2: Research collaborations of surveyed public researchers

Type of collaboration	Average per researcher, 2019	Share of researchers, 2019	Share of researchers, entire career
Collaborative research involving companies	0.72	27.8%	42.54%
Contract research to companies	0.58	21.38%	35.04%
Technical assistance services to companies	0.42	16.2%	21.87%
Technology extension services to companies	0.19	10.5%	17.22%
Collaborative research with government	0.30	18.14%	28.51%
Research contract services to government	0.43	12.78%	20.85%

Source: Authors' calculations | Note: Responses are weighted by academic field.

Table 3: Staff exchange activities and other forms of knowledge transfer by surveyed public-sector researchers (total sample)

Type of staff exchange	Average per researcher, 2019	Share of researchers, 2019	Share of researchers, entire career
Conducting PhD projects with industry	0.39	20.2%	24.1%
PhD projects in industry (junior researchers)	0.35	4.8%	6.4%
PhD projects in industry (senior researchers)	0.40	15.7%	17.7%
Training activities provided to industry or government	0.67	19.8%	25.16%
Sabbatical or short employment residency in industry or spinoff	0.02	1.13%	4.4%
Personal exchanges with other public research institutions or governmental agencies	0.22	13.8%	18.34%
Other consultancy services and advisory work	0.74	26.8%	30.13%

Source: Authors' calculations based on the results of the World Bank Survey of Bulgarian Researchers (2020).

Notes: (1) Responses for Bulgarian researchers are weighted by the distribution of population of researchers (at both PROs and HEIs) per large sector field of research following the classification of UNESCO. (2) We considered researchers as junior researchers if he/she reports job status 1: Full time young researcher (Doctorate student or Post-doctorate) or 3: Part time young researcher or has at least 15 years of experience and without managerial position.

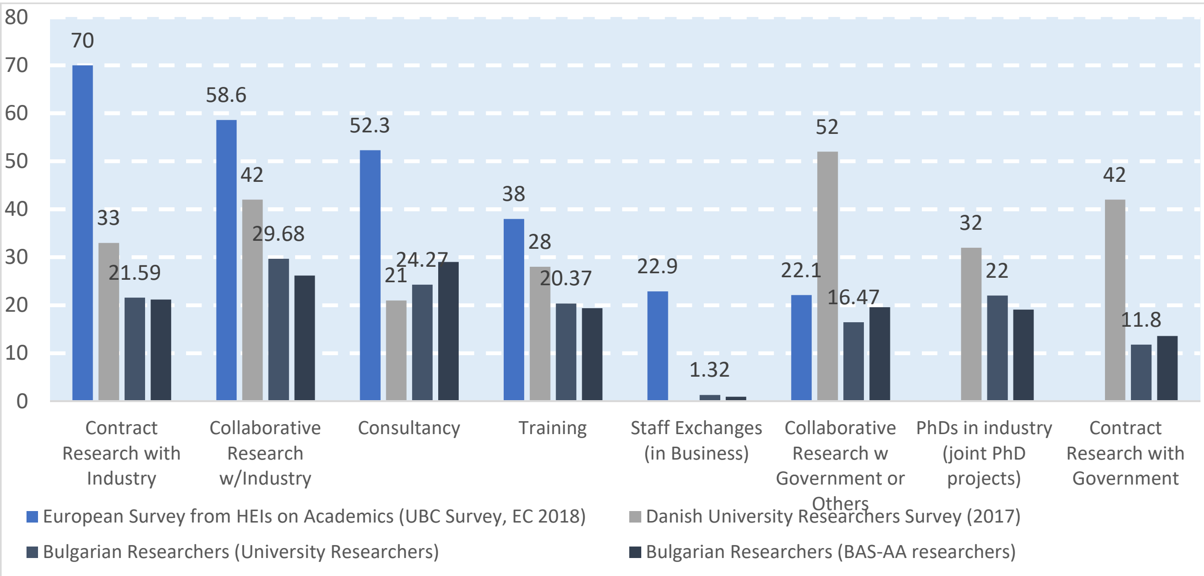
Looking at staff exchanges with industry and other research and government organisations and other forms of knowledge transfer, short-term activities such as consultancy and advisory services are the most frequent form of knowledge transfer (performed by 27 percent of researchers), followed by training services and PhD projects with industry (both were performed by 20 percent of surveyed researchers in 2019) (Table 3). Looking more closely at PhD projects in industry, only five percent of junior researchers participated in such projects in 2019, whereas 16 percent of senior researchers participated (likely as a supervisor) in one or more PhD projects in industry in 2019. Personnel exchanges (sabbaticals or secondments or short employment residency) are less common, with slightly more than one percent of researchers being engaged in this activity.

3.2 How do these trends compare to other European countries?

Bulgarian researchers perform far below European average trends in knowledge and staff exchange activities, especially in terms of contract research with industry and training and consultancy services (Figure 4). Only 1.3 percent of Bulgarian researchers participated in staff exchanges with industry in 2019, as opposed to an average of 23 percent in European countries. Similarly, the EU average for collaborative research with industry is 59 percent, while only 28 percent of Bulgarian researchers engaged in such activities. The only area where Bulgarian researchers perform close to the EU average is in collaborative research with government (or with other PROs). While there is no EU survey data on PhDs in industry, a recent survey of Danish academics finds that one-third of Danish academics are or were involved in PhD projects in industry, compared to less than a quarter of Bulgarian researchers. Involvement in contract research with government is also much higher in the Danish survey (42 percent vs 12 percent of Bulgarian researchers).

Commercialisation outcomes, in the form of licensing agreement, spinoffs[7], or startups[8] are very low. Among surveyed researchers, the leading forms of commercialisation outcomes in 2019 were entering into confidentiality agreements[9] (six percent of surveyed researchers entered into such agreements in 2019) or material transfer agreements[10] (three percent of surveyed researchers in 2019) (Table 4). Only two percent of surveyed researchers entered into a licensing agreement or the reassignment of IP rights in 2019, while three percent participated in the creation of a spinoff and only two percent participated in the creation of a startup involving licensing of IP rights or other results from their research.

Figure 4: Participation in collaborative research and research services: Comparison with EU average participation



Sources: Indicators for Bulgarian researchers come from the World Bank Survey of Bulgarian Researchers (2020); indicators for the European averages are from Davey et al., (2018), a European Commission study based on a survey of researchers at HEIs. Indicators for Danish researchers are from the 2017 Triple-I-Research Survey of Academics.

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[7] Spinoffs are defined as new firms involving the participation of an academic or student.

[8] Startups are defined as new companies founded by entrepreneurs external to the HEI or PRO and based on technology created by the HEI or PRO.

[9] Confidentiality agreements are legal agreements that bind one or more parties to non-disclosure of confidential information.

[10] Material transfer agreements are contracts that govern the transfer of tangible research materials between two organizations, where the recipient intends to use said materials for their own research purposes.

Table 4: Technology transfer activities of surveyed public-sector researchers -average number of activities or contract/´project involvement, 2019 (Total Sample)

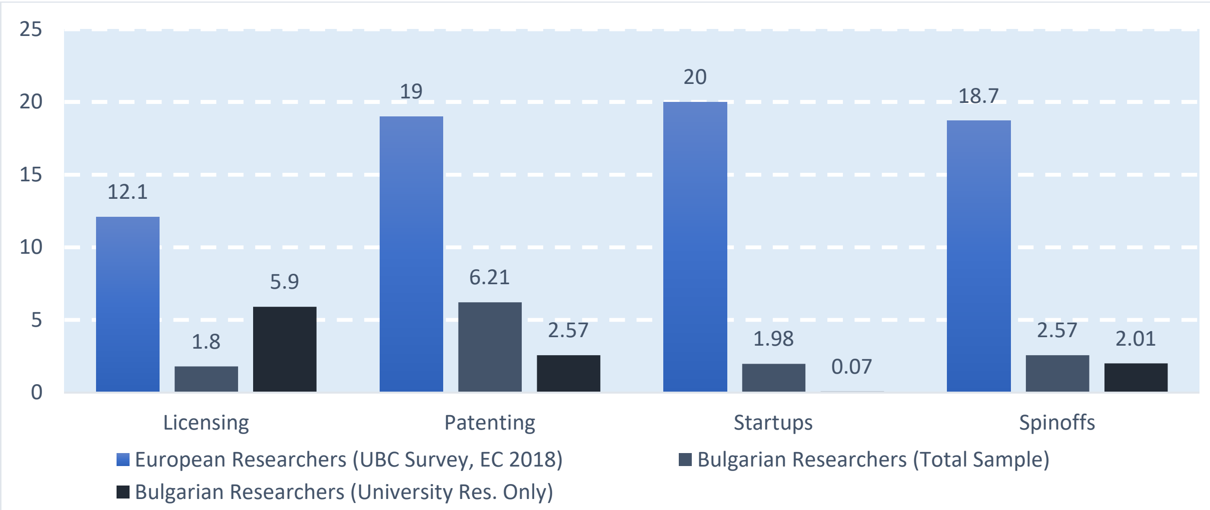
Type of TT activities	TT activity per researcher	Share of researchers with n>0
Licensing and/or assignments of IP rights	0.5	1.8%
Material transfer agreements	0.11	2.66%
Confidentiality agreements	1.4	6.1%
Spinoff creation	0.2	2.57%
Startup creation through licensing of IP rights	0.1	1.98%

Source: Authors' calculations based on the results of the World Bank Survey of Bulgarian Researchers (2020).
Notes: Responses for Bulgarian researchers are weighted by the distribution of population of researchers per large sector field of research, following the classification of UNESCO and distribution population of 2017.

Patenting and commercialisation rates of Bulgarian researchers are low compared to the results shown in recent European surveys of public researchers. While 19 percent of researchers in European HEIs were awarded a patent in the 12 months before being surveyed, only six percent of Bulgarian researchers were awarded a patent in 2019 (Figure 5). The share is even lower for Bulgarian researchers working in HEIs (three percent). Only two percent of researchers in Bulgarian researchers participated in startup creation in 2019, while 20 percent of surveyed European researchers did in 2017.

As reported in previous studies, commercialisation activity differs across the disciplines of surveyed researchers. According to our survey for researchers, researchers in engineering and technology fields are more likely to engage in knowledge exchange activities with industry and less likely to engage in exchanges with other government or research organisations, compared to researchers in other fields (Figure 6). Engineering fields report the largest shares of researchers´ involvement in research collaboration and research contracts with industry, with rates about two or three times larger than the average- as well as high shares in the provision of training services and PhDs in industry. Researchers in computer sciences are more likely than those in other disciplines to participate in knowledge exchanges with government and other research organisations and to engage in technology extension services. Notably, commercialisation outputs are low across all disciplines.

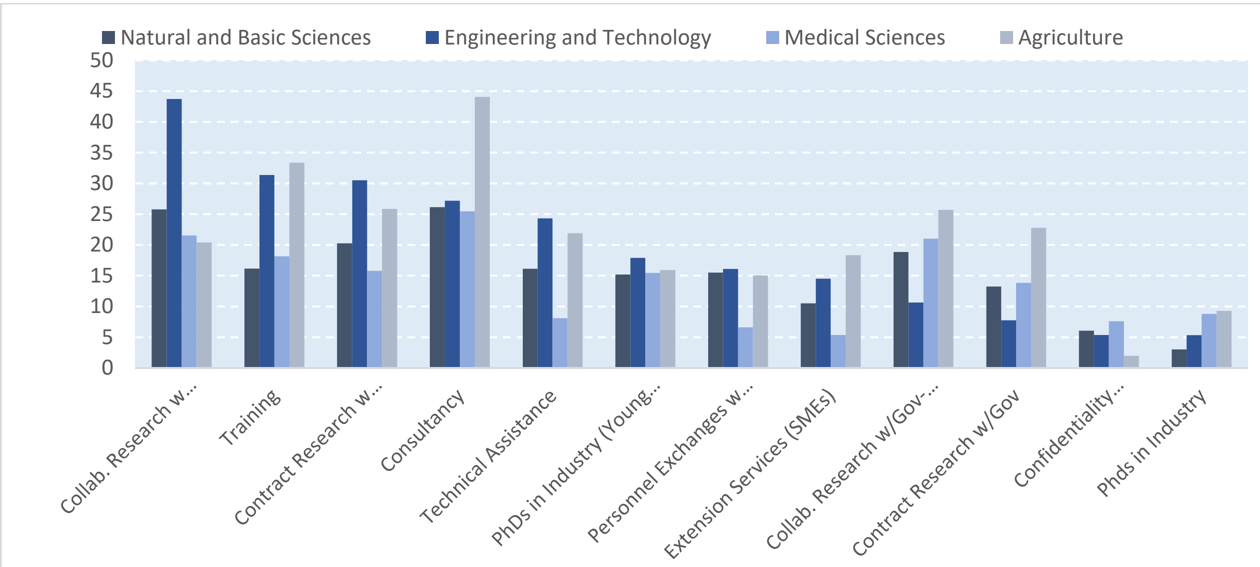
Figure 5: Commercialisation of research results through licensing and new firms (total sample)- Comparison with EU trends (% of researchers involved over the last twelve months)



Sources: Indicators for Bulgarian researchers come from the World Bank Survey of Bulgarian Researchers (2020); indicators for the European averages are from Davey *et al.,* (2018), a European Commission study based on a survey of researchers at HEIs. Figures for the Bulgarian data cover researchers at both HEIs and PROs.

Notes: In the European Survey, spinoff participation refer to the proportion of academics who have been involved in the creation of one or more spin-offs created from their research in the last 12 months.[11]

Figure 6: Knowledge exchange and commercialisation activities by field of respondent



Source: Authors' calculations based on the World Bank Survey of Bulgarian Researchers (2020).

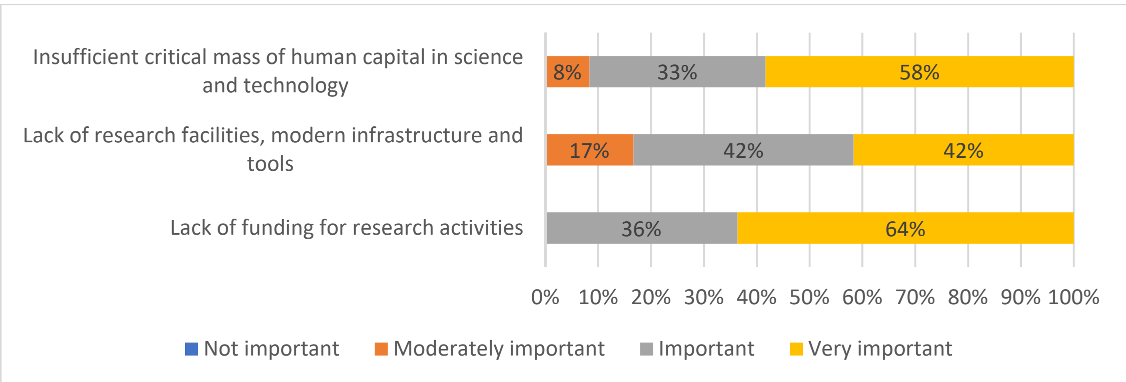
[11] The indicator on patenting in the European Survey refers to registered patents (applied patent applications) based upon their research during the last 12 months. The same definition is used in the Bulgarian Survey, but here we report whether researchers participated in patent applications filed domestically.

Notes: Responses are weighted by the distribution of population of researchers (at both PROs and HEIs) per large sector field of research following the classification of UNESCO and population distribution of 2017.[12]

3.3 Research Capacity and Institutional Strategies

Bulgarian PRO and HEI research strategies and plans are largely aligned with national-level strategies, though not all organisations have established such strategies. Research capacity appears to be a major challenge for Bulgarian research institutions, due to limited of funding and human capital and inadequate research infrastructure. A majority (79 percent) of interviewed PROs and HEIs have a defined research strategy or plan for the institution, and other six percent are in the process of developing one. Public institutions are heavily reliant on public funding, and public funding instruments are aligned with the research priorities in one of the country's key research strategies, which include the National Strategy for Development of Scientific Research 2017-2030 and the Innovation Strategy for Smart Specialisation. PROs and HEIs are monitored by MoES regarding their impacts in achieving the priorities of each program. Because of their dependence on national funding instruments, most PROs and HEIs have established an institutional strategy or plan for research aligned with these national research priorities. Research capabilities appear to be a major challenge for public research institutions, which includes an insufficient critical mass of human capital, lack of adequate research facilities and infrastructure, and lack of funding for research activities (Fig. 7).

Figure 7: Capacity issues impeding research and technology transfer according to PROs and TTOs



[12] Engineering and technology research areas covers: Mechanical Engineering: Electrical Engineering Chemical Architecture, construction and surveying, technology Environmental Engineering and operation and Transportation, and biotechnology. Natural and Basic Sciences: biology, chemistry physics, mathematics & computer sciences.

Source: Authors' calculations

Insufficient research funding was cited as a very important or important challenge by 100 percent of PROs/HEIs and researchers surveyed. As described in the section on general trends in public research, public investments in R&D are the lowest in the EU on a per capita basis, and public research institutions perform a very low share of research nationally, due in large part to the low levels of research funding available to these institutions. The only new source of public research funding in the current programming period is the OP SESG, which has primarily focused on the development of new Centres of Competence (CoCs) and Centres of Excellence (CoEs)[13]. Outside of the CoCs and CoEs, there are no OP instruments that specifically fund public research, although some of the instruments in the current Operational Programme Innovation and Competitiveness can provide funding to PROs and HEIs as partners in research collaborations with industry. Low levels of public R&D investment also contribute to the lack of human capital and adequate infrastructure.

A lack of a critical mass of human capital was also cited as a very important or important challenge to conducting impactful research by 92 percent of PROs/HEIs and 60 percent of public researchers, highlighting the need to improve the size and quality of the public sector research workforce with more competitive salaries for researchers and academics. Public researchers receive very low average salaries relative to their CEE peers and the domestic and international private sectors, making it difficult for PROs and HEI to attract and retain researchers. In the 2017 Survey on Researchers in European Higher Education Institutions, Bulgarian public researchers at all career stages expressed dissatisfaction with their renumeration – sentiments shared by researchers in many CEE peer countries (Janger *et al,* 2017).

An additional challenge is the lack of adequate research facilities, which was cited as a very important or important challenge by 83 percent of PROs/HEIs and 80 percent of researchers. Yet substantial investments have been made in the construction of new public research infrastructure under the current OP SESG, as well as under the National Roadmap for Research Infrastructure 2017-2023 and National Science Programs 2018-2022. However, there are scant funds available for the maintenance and operation of existing infrastructure. PROs and HEIs often need to find

[13] These Centres are intended to bring together the research capabilities of the BAS, national universities, and other key scientific and business organizations, with the objective of consolidating research capabilities, improving research infrastructure, forming partnerships and linkages between research actors, and raising the level and market orientation of the research activities of participating research organizations.

funding sources to cover operational costs, such as utilities, replacement equipment parts, and research materials, as these costs are not fully covered by institutional or project funding.

3.4 Governance and Strategy Definition: The Importance of Industry Consultation

Governance structures influence the way institutions maintain research standards, engage in collaborative research, and interact with other actors in the innovation system (Intarakumnerd and Goto, 2018). Key governance features that promote connection with external actors of the innovation system include -among others: institutional and operational autonomy (e.g. Cruz-Castro and Sanz-Menendez, 2018); governing bodies (i.e. trust boards and institutional research bodies) with involvement of industry representatives and regional actors -public and private (OECD, 2018; Intarakumnerd and Goto, 2018); definition of research agendas and goals (medium or long term agendas), and the use of monitoring and evaluation practices -which should include or consider measures of knowledge and technology transfer activities (OECD, 2014; 2018).

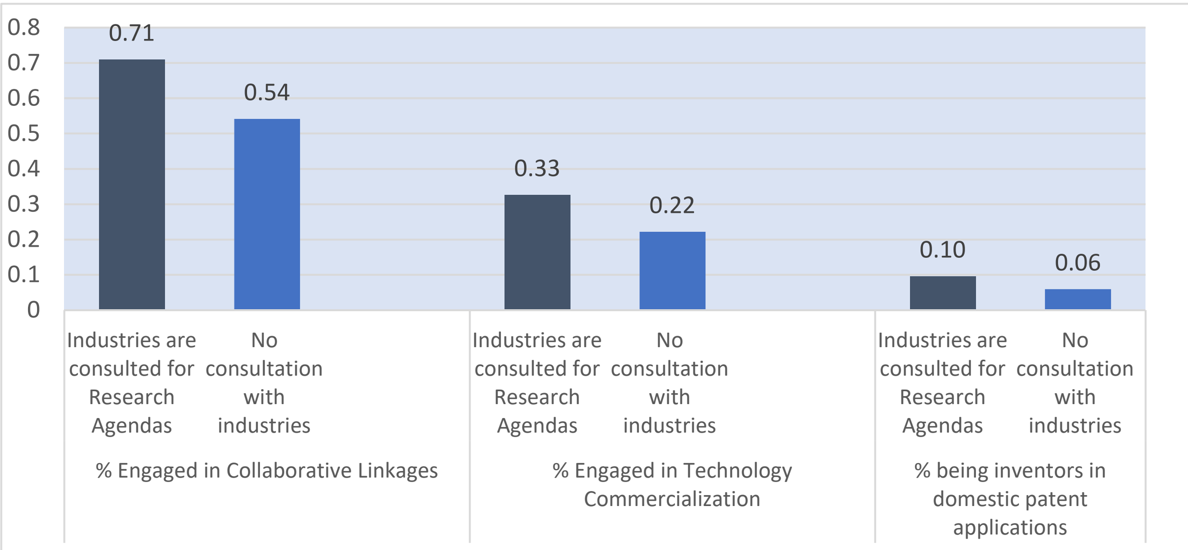
The consideration of industry demands for knowledge (largely in the form of technological challenges) in public research agendas is a fundamental factor in making publicly-funded research relevant to the economy, and mechanisms for soliciting industry input must be in place in public research institutions. The experiences of leading PROs in Germany, Taiwan, Japan, Australia, and the US show that industry involvement in steering and advisory boards and funding schemes are key factors that influence how relevant research is to industry and society, as well as influence the level of knowledge transfer outside of institutions.

Connecting with industry demands is a major challenge for Bulgarian S&T institutions. Bulgarian PROs do not have industry representatives on governing boards due to statutory restrictions, nor is industry consulted on the definition of institutional research priorities by PROs or HEIs. These statutory restrictions do not apply to universities, and Bulgarian universities are mandated to have industry representation on governing boards. All public research institutions have some form of governing body (e.g., scientific councils, boards of trustees, etc.) to help articulate research priorities and objectives; of the surveyed institutions, 93 percent of PROs and 66 percent of HEIs reported that they have a steering or trust board for the definition of strategic goals.

None of the surveyed organisations have formal mechanisms to consult with industry on defining research priorities. The lack of formal consultation mechanisms with industry and society limits the effectiveness of such steering bodies and hinders the relevance of research undertaken by these organisations. This is a major gap in the link between the public and private sectors and means that decisions that inform the supply of public research are not necessarily in line with industry demands. However, 53 percent of public researchers believe that their institutions consult with industry for the definition of research agendas and human capital formation, which indicates that more informal consultations with industry are occurring at these organisations.

Evidence from the researcher survey (Figure 8) shows that researchers whose institutions have mechanisms in place for consultation with industry show higher propensity to engage in collaborative linkages and technology commercialisation. Researchers in institutions that have such mechanisms report a much higher rate of engagement in collaborative research (71 percent) and commercialisation activities (33 percent), as opposed to researchers located in institutions without such consultation (54 percent and 22 percent respectively).

Figure 8: Researchers whose institutions consult with industry on research priorities engage in more knowledge exchanges and technology transfer activities



Source: Authors' calculations.

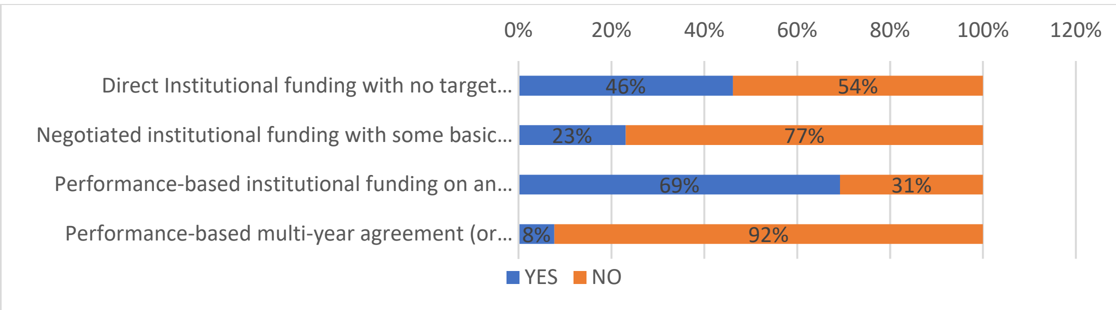
3.5 Funding Sources and Performance Implications

Sources of funding, to a large extent, influence the strategic focus and innovation activities of research organisations. Performance-based funding, where a portion of the agency budget is allocated according to specific performance targets, is way to incentivise desired institutional behaviors and outcomes, such as research excellence, greater industry-research linkages, and knowledge transfer. In Europe, the introduction of performance-based funding systems has been one of the central mechanisms through which many EU member states have tried to increase the effectiveness and performance of public sector research systems (European Commission, 2009; Jonkers and Zacharewicz, 2016). External funding is highly encouraged by policy makers (e.g. industry funding and competitive grants) as a signal of research relevance and linkages with industry and the international community in research and innovation.

Interviewed institutions are highly dependent on direct institutional funding, accounting for about half of total funding (49 percent) for PROs. PROs' own revenues from consulting, contracts, and fees made up 23 percent of funding received; other public funds, largely in the form of competitive grants, represented 19 percent of funds, while private sector funded research was less than one percent of funding received (only two of the 13 surveyed PROs received any funding from the private sector). In principle, this ratio of own revenues (in total funding) is not far from the average in European PROs, and very far from typical shares reported in leading European PROs such as VTT in Finland, where about two thirds of funding comes from external sources, or the Fraunhofer Institutes in Germany which typically have one third of total funding coming from own revenues derived from commercialisation and services.

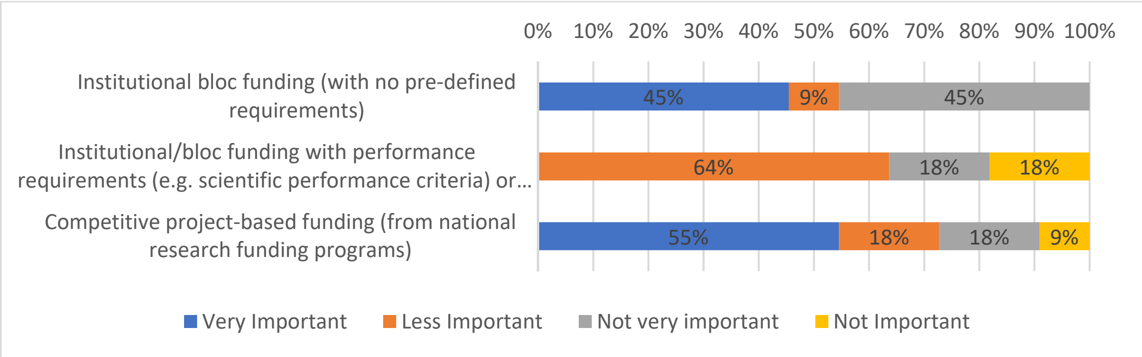
The survey of public researchers also shows low levels of private sector funded research: in 2019 only 21 percent of surveyed researchers conducted privately funded research and 11 percent provided technology extension services to companies. This low level of engagement with the private sector may be indicative of a lack of connections between the public and private sectors, but also may be the result of regulatory barriers for such linking.

Figure 9: Institutional funding schemes of surveyed PROs



Source: Authors' calculations.

Figure 10: Importance of funding sources for surveyed PROs



Source: Authors' calculations.

While all public research institutions can receive PBRF with multiannual plans and performance contracts (Ministry of Education and Science, 2016), survey results suggest that it is not yet a meaningful source of funding. 46 percent of surveyed PROs receive block funding with no target requirements of any kind, and 23 percent receive "informal" performance-based funding based on negotiated basic performance indicators. While 69 percent receive some formal performance-based funding on an annual basis, only eight percent received performance-based funding from multi-year contracts (Figure 10). When asked about the importance of these different types of institutional funding, 45 percent of PROs consider block funding with no performance requirements to be a very important source of funding, while no PROs consider performance-based funding to be a very important source of funding (Figure 3).

Bulgaria has set a target for at least ten percent of direct institutional funding to be performance based. However, at present, PBRF only accounts for roughly 2.5 to five percent of total institutional funding for PROs and HEIs, depending on the type of institutions. Accelerating cultural change will require that Bulgaria gradually increase the share of PBRF to meet and potentially exceed its ten percent minimum target for PBRF. In Denmark and Sweden, this ratio is 19 percent and 20 percent respectively, with planned increases over time. In the Czech Republic, 20 percent of total funding for research is based on the results of research performance evaluation.

A recent expert study (European Commission, 2018a) strongly recommended to increase the use of the PBRF in Bulgarian public research institutions as a tool for change. However, greater use of PBRF will not solve all the structural problems that hamper the performance of the Bulgarian public research sector. Structural reforms of the Bulgarian public research landscape such as to reduce the very high fragmentation of the research system (many small units) are a pre-condition for PBRF to be effective. The lack of capacity and critical size are also major handicaps to the effectiveness of new funding policies and policies aiming to improve the impact of public research (European Commission, 2018a).

3.6 Technology Transfer Capacity and Intellectual Property (IP) Policy

IP frameworks are key to technology commercialisation, as they provide legal clarity about the ownership and management of intellectual outputs at these institutions. By providing a legal framework, and vesting ownership rights over IP, these policies reduce uncertainty (about ownership) and transaction costs related to asymmetry and agency problems surrounding commercial transactions with private entities (Siegel et al., 2007). The literature explains that the allocation of ownership rights over research results defines the pecuniary reward to PROs and researchers and is of central importance. This contributes to the development of a more formal and systematic process of technology transfer and the articulation of intermediation networks (e.g. TTOs and technology brokers; etc.,).

For developed countries, a large body of evidence exists regarding the impact of policy reforms regarding IP in academic institutions, such as the Bayh–Dole Act in the US and the abolition of the so-called 'professor's privilege' in several European countries (Mowery and Sampat, 2005; Powers and McDougall, 2005). Although mixed evidence exists for European countries regarding the effects of such reforms on industry-science collaboration propensity by researchers and academic patenting or startups (e.g. Czartinscky et al., 2016), the literature mostly agrees on positive effects regarding institutional change and the development of local IP practices in institutions and the adoption of a more entrepreneurial culture. In addition, such reforms help clarity existing (and often conflicting) regulatory frameworks helping harmonise institutional rules and settings governing IP policies across universities.

The international experience has shown that incomplete legislative frameworks in the areas of IP, technology transfer, and science-business linkages can be serious impediments to the capacity of HEIs and PROS to commercialise the results of the research activities. In Bulgaria, while national IP and technology transfer legislation is generally in line with international norms and standards, there is no clear legislation governing who owns IP generated by public research institutions (PROs and HEIs) and there is also no specific technology transfer law, such as the U.S.'s Baye-Dole Act, that clarifies the ownership and commercialisation rights of actors and governs the transfer of public research to private applications (Spacic et al., 2019). Further, procedures are vague, bureaucratic, and not well understood by the public research institutions, which makes it difficult on the part of PROs and HEIs, as well as private sector counterparts, to collaborate in technology transfer or research activities. As a result of these gaps in the policy framework, IP policies regarding ownership and commercialisation vary significantly by institution. The question of ownership of IP generated by public research institutions was devolved to the individual institutions by the 2016 amendments to the national Higher Education Act, which states that every HEI should have a system for IP protection, management, and ownership. To address these requirements, each institution had to develop its own internal regulations.

Further, public institutions generally lack sustainable funding and resources for IP and tech transfer activities, and few of these institutions have a defined strategy for technology transfer and/or entrepreneurship in place. There is also a general lack of awareness among public researchers of national and institutional technology transfer policies. Among surveyed organisations, most public institution (92 percent of PROs and 67 percent of HEIs) retain ownership rights over IP resulting from research funded by public sources, while roughly half of the organisations (58 percent of PROs and 50 percent of HEIs) provide ownership rights to inventors (Figure 5).[14] A smaller share of organisations (50 percent of PROs and 17 percent of HEIs) provide ownership rights to public funding organisations.

Unsurprisingly, IP policies appear more flexible for privately financed research, with PROs and TTOs ceding ownership to third parties more often – 67 percent of PROs and 86 percent of HEIs provide ownership to private sector funding organisations (Figure 6). Still, a relatively large share (42 percent of PROs and 33 percent of HEIs) retain ownership of IP for themselves in privately financed research (which runs counter to standard international practices) and 25 percent of PROs and 67 percent of HEIs provide ownership to inventors. This shows there is a large degree of heterogeneity in IPR ownership rules across public research institutions.

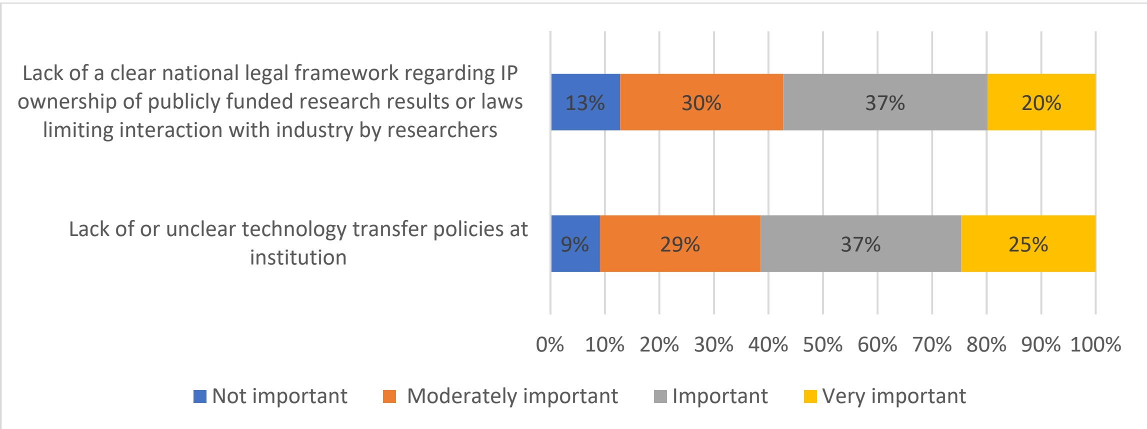
Only 16 percent of the interviewed institutions have a defined strategy for technology transfer and/or entrepreneurship; half of the interviewed TTOs have a tech transfer strategy and none of the interviewed PROs have such a strategy in place. As noted in the previous section, public research institutions, which are heavily reliant on public funding instruments, have adopted strategies

[14] Note that in many instances, ownership of IP is not mutually exclusive: ownership can be shared by PROs/HEIs, funding organizations and/or inventors, depending on the circumstances.

aligned with the research priorities in one of the country's key research strategies. However, none of the key national strategies have technology transfer priorities. Thus, these institutions do not have funding-related incentives to develop their own technology transfer strategies.

According to the results of the public researcher survey, researchers feel that there are IP and technology transfer policy challenges at both the national and institutional levels. 57 percent of researchers believe that the lack of a clear national legal framework on IPR ownership and laws regulating interactions with industry present an important or very important barrier to technology transfer impacts, and 62 percent believe that the lack of (or unclear) technology transfer policies at the institutional level also represent an important or very important obstacle (Figure 11).

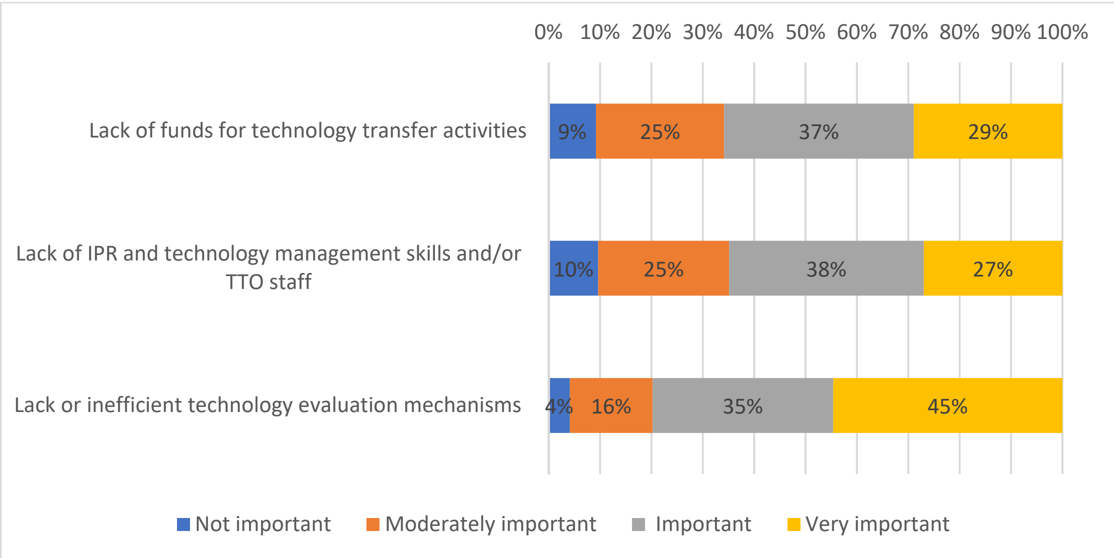
Figure 11: Challenges related to national and institutional TT policies according to public researchers



Source: Authors' calculations based on survey of public researchers.

Public institutions generally lack sustainable funding and resources for IP and tech transfer activities. Not all PROs and HEIs have dedicated TTOs, and some of the TTOs are more project-oriented and do not have the transfer of technologies from the institution to industry as a central feature of their business model. BAS has a single centralised tech transfer unit, and the individual institutes may not have dedicated IP experts. Public TTOs suffer from a lack of sustainable funding – in the previous EU programming period, significant investments were made, primarily with EU funding, to develop TTOs at several Bulgarian public research institutions. However, when the EU funding ceased, national funding was not made available to maintain these offices, which then lost much of the staff and skills that had been developed (Spacic et al, 2019). A recent World Bank analysis of the Bulgarian STI policy mix finds no instruments that provide direct funding for technology transfer activities or TTOs (Aridi et al. 2020). The current OP SESG does not include any instruments that support technology transfer activities or TTOs at public institutions outside of the CoC and CoE projects. The researcher survey also shows that a lack of resources for technology transfer presents a challenge to improved commercialisation impacts of public research, with over 60 percent of researchers stating that the lack of funding, technology evaluation mechanisms and IP management skills are important or very important barriers to improved tech transfer impacts (Figure 12).

Figure 12: Availability of technology transfer resources according to public researchers



Source: Authors' calculations

3.7 Academic Incentives

Academic incentives for engaging in industry collaborations and knowledge and technology transfer activities are set by the national statutes[15] stipulating the minimum requirements for academic titles at HEIs and PROs. These statutes, while including measures for IP generation, do not include indicators for commercialisation outcomes (such as licenses or spinoffs) or collaborative research activity in the career development metrics of faculty and research staff in HEIs and PROs. Such indicators are also not present in the reviewed policies of individual institutions. This is a major gap in the incentive framework. The international experience has showed performance evaluations that only include IP metrics without considering the actual

[15] *Law on the Development of Academic staff* and the corresponding *Rules for the Implementation of the Law on the development of Academic Staff.*

transfer and exploitation of research results are limited in their ability to change behavior to achieve desire tech transfer results.

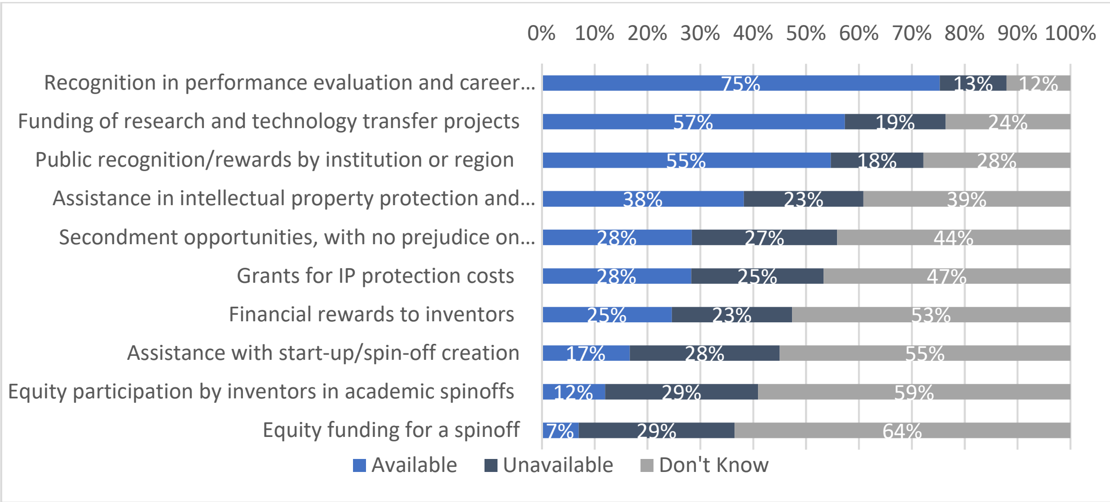
There is also no legislation that defines the benefits that should come to inventors if their inventions are commercialised; these issues are regulated by institutional IP policies and the individual contracts between PROs and researchers. This regulatory gap is in large contrast with national incentive frameworks in most European and OECD countries, which in many cases cover these matters in in national technology transfer laws, innovation laws, and in national-level reforms to S&T regulations. Previous reports on the incentive framework in Bulgaria reinforce these findings; Soete *et al.,* (2015) find a lack of coherent policies and incentives for encouraging the creation of IP, which has impeded the commercialisation of public research. Galev (2011) and Spacic et al (2019) find that, due to the lack of incentives and resources for technology transfer, public researchers will often commercialise IP as individuals and sometimes create their own spinout companies without institutional knowledge or support.

The most common incentives are related to recognition of research and tech transfer achievements and funding for research projects, as more than 50 percent of surveyed researchers said these incentives were offered by their institutions. Assistance in IP protection, and management (38 percent), grants for IP protection costs (28 percent), and secondment opportunities (28 percent) were less common, while financial rewards for inventors (25 percent), assistance with startup/spinoff creation (17 percent), equity participation in spinoffs (12 percent), and equity funding for a spinoff (7 percent) were very uncommon incentives offered to public researchers. Surveyed researchers are largely unaware of their institution's policies and incentives related to technology transfer and knowledge exchange, with more than half of respondents unaware of the availability of many of the forms of incentives included in the survey (Figure 13).

The lack of incentives offered to public researchers is concerning because the availability of such incentives has a demonstrated impact on Bulgarian researchers' knowledge activities, IP outputs, and commercialisation outcomes. Among surveyed researchers, those researchers who engaged in mobility programs with industry, such as sabbaticals and secondments (or having joint positions industry-academia) are more likely to engage in research collaboration and contract research with the private sector and have higher levels of licensing and startup activity (Figure 14). Similarly, researchers who received financial rewards for licenses of academic spinoffs engage significantly more often in industry collaborations, patenting, and commercialisation (Figure 15).

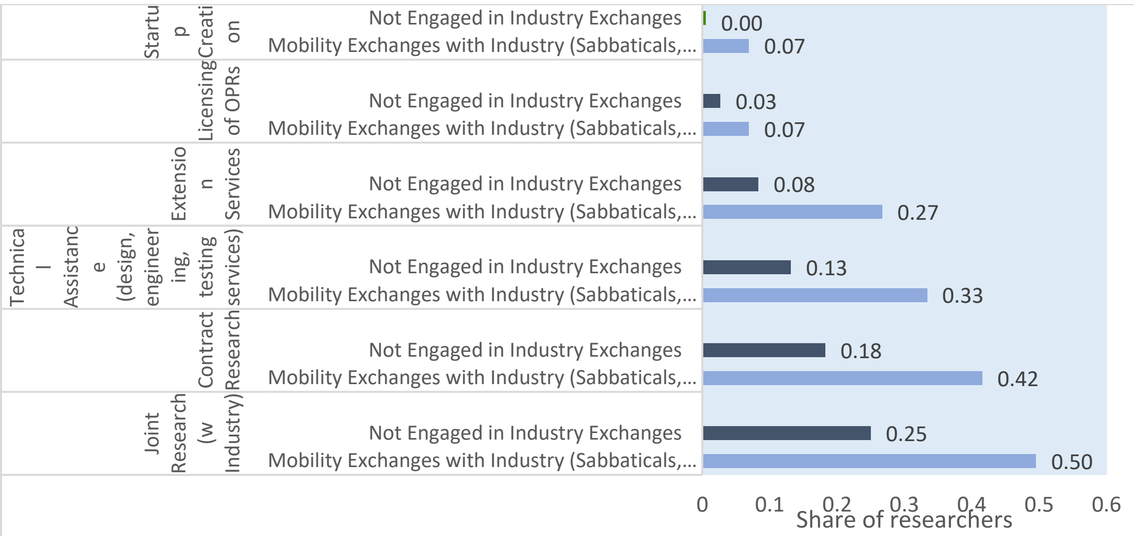
This is in line with a large body of research that confirms the importance of royalty participation rights in the involvement of university researchers in technology licensing activity and patenting.

Figure 13: A large share of Bulgarian researchers had little information on incentives for technology transfer engagement, 2020



Source: Authors' calculations

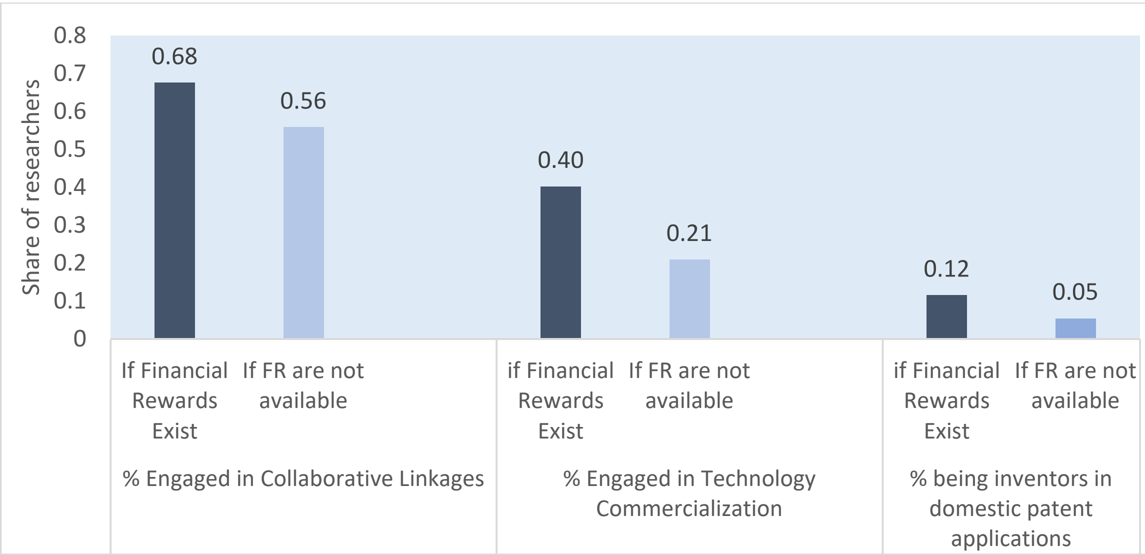
Figure 14: Staff exchanges with industry are key catalysers of knowledge exchange and technology transfer



Source: Authors' calculations

It is unclear whether recognition through performance evaluations and career advancement encourage more technology transfer or knowledge exchange activity among surveyed researchers. There were no significant differences between researchers who receive such evaluations and those who do not in terms of publications, linkages with industry, or commercialisation. This could be due to several factors: First, the national performance evaluation framework was only recently amended in 2018 to include IP outputs and project funding raised, and there may not have been enough time for these changes to have an impact. Alternatively, the evaluation framework does not include commercialisation outcomes (only IP outputs, such as patents or utility models), and thus does not incentivise technology transfer activities directly. Another possibility is that the effects of the updated framework and its impact on career progression and salaries may not be apparent to researchers, thus limiting its effects on researcher behavior.

Figure 1: Financial incentives are associated with stronger industry-science collaboration



Source: Authors' calculations

4. Policy Discussion and Conclusions

Previous studies on the Bulgarian knowledge transfer framework have identified several obstacles to technology transfer, particularly a lack of funding and a lack of consolidated research base, hindered by excessive fragmentation and insufficient policy incentives for both researchers, and institutions. According to our evidence, research institutions (PROs and TTOs) and public researchers agree on the major obstacles to research excellence and technology transfer: a lack of communication between the public and private sectors, research that is not aligned with the needs of industry, a lack of policies to promote public-private collaboration, lack of funding for research, insufficient human capital, and a lack of adequate research facilities.

Furthermore, the survey has shown that public research institutions and universities suffer from weak governance design; they do not include external actors (such as industry representatives) on their governing boards or councils, and rarely consult with industry for strategy and priority setting. This seriously limit chances for addressing innovation demands and develop linkages with the private sector. Most public institutions surveyed are heavily reliant on institutional block funding, as opposed to performance-based or competitive funding. These factors limit the effective functioning of these institutions and their performance, in terms of interactions with external actors and knowledge transfer impact.

There are several clear areas for action and improvement based on the key challenges identified in this study. First, to strengthen opportunities for collaboration with the private sector and leverage technology transfer activities, it is fundamental to foster a more open system, with special attention to facilitating mobility of researchers and personnel exchanges (bilateral mobility) across organisational boundaries, especially with the private sector. This can take the form of secondments, sabbaticals, joint positions and especially through PhDs in industry. Equally important is to allow the leverage of private funding for R&D through collaborative grant schemes with industry and private R&D funding for projects. This will require revisiting corresponding regulatory frameworks for PROs and HEIs.

Second, to enhance the policy framework for technology transfer, it is fundamental to improve and clarify the national policy framework for IPR ownership and improve academic incentives for researchers. For this, it is critical to develop a coherent national framework for IPR and technology transfer. This can be done through for instance the creation of a national-level legislation or policy that governs ownership of IP generated by publicly funded research and the transfer of public research to private applications, rather than devolving the question of IP ownership to individual institutions. Regarding the provision of financial incentives for researchers, such legislation should consider and acknowledge the right for scientists to participate in royalties from IP resulting from their research activities (licensing and selling of IP). Additional financial incentives could also be considered.

And third, the set of incentives for public scientists to engage in high quality research, and knowledge transfer, and commercialisation activities should be reinforced substantially. This would entail not only the concession of financial rights in technology commercialisation activities (licensing and selling of IPRs and equity participation in startups) but also increasing current salaries -which are among the lowest in Europe. As in the case of Poland with the recent *2018 Science Law* reform, it is important to conduct a revision of salaries and remuneration policies and more broadly of science careers in both public research organisations and the academic sector. This will also mean to acknowledge technology transfer and collaborative research activities in career development and salary progression of researchers.

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