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SPECIAL ISSUE

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UNIVERSITIES
IN INNOVATION SYSTEM

10 years
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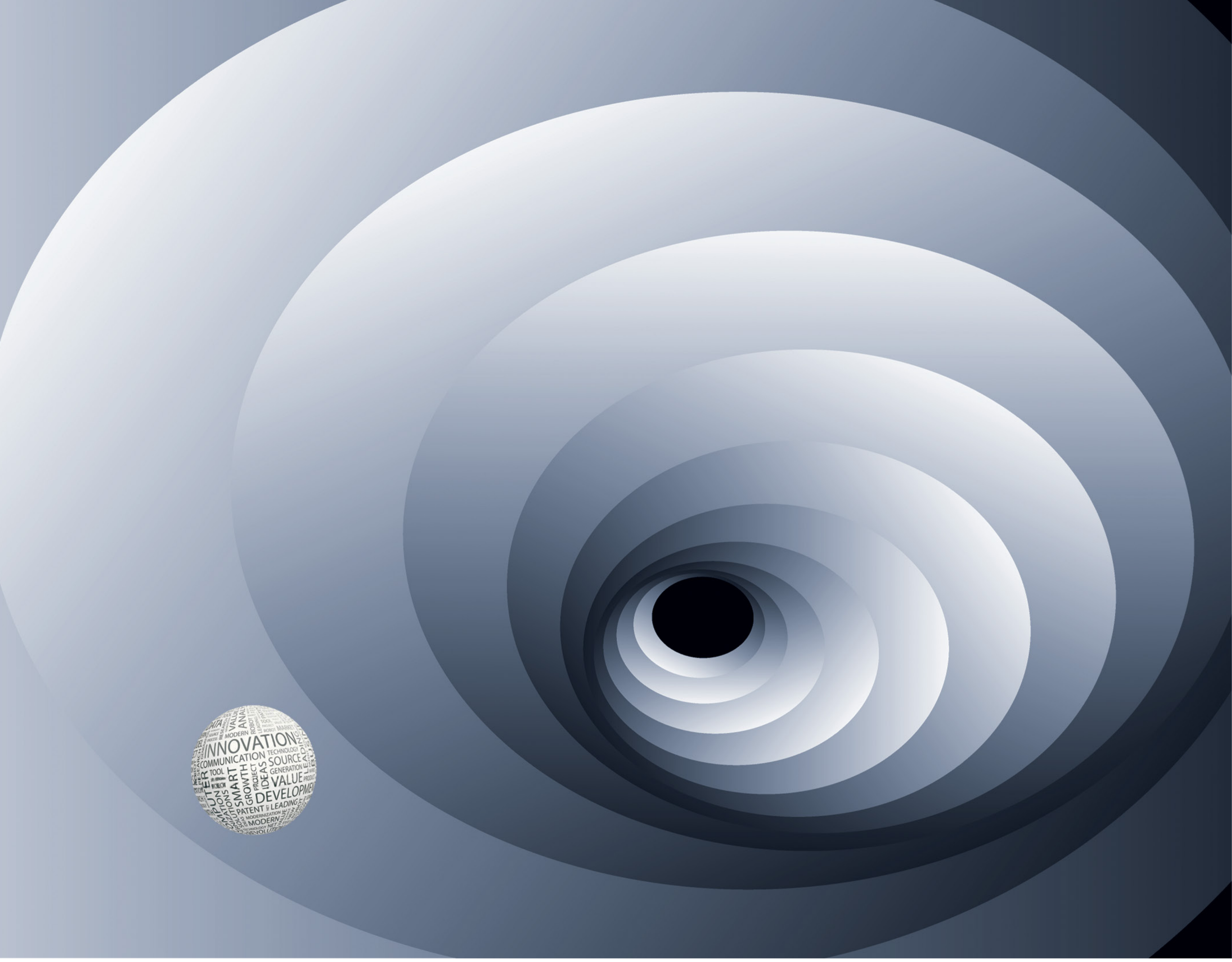
the future


INNOVATION
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STRATEGIES
Robotics: Breakthrough Technologies, Innovation, Intellectual Property
Abstract

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ABOUT THE JOURNAL

Foresight and STI Governance (formerly *Foresight-Russia*) is an open access journal established by the National Research University Higher School of Economics (HSE) and administered by the HSE Institute for Statistical Studies and Economics of Knowledge (ISSEK), located in Moscow, Russia. The mission of the journal is to support the creation of Foresight culture through the dissemination of the best national and international practices of future-oriented innovation development. It also provides a framework for discussing S&T trends and policies.

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The Role of Universities in the Knowledge Triangle

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The concept of the Knowledge Triangle formalizes the interaction between the long understood "core" missions of Higher Education Institutions (HEIs): teaching, research and public service. In particular, the Knowledge Triangle refers to the generation of knowledge by HEIs through their activities in education, research, and in a wide variety of interactions with the wider public that assists in the application of new knowledge in the form of new products, processes, and services. Each of these three elements interacts with and influences the others. The resulting bi-directional or circular knowledge flows between the three core elements of the knowledge-building process constitute the Knowledge Triangle (see Cervantes, and Polt and Unger, Figure 1, this special issue). Of course, these flows depend on tools to mobilize resources to create value for the members of the knowledge network (stakeholders), including actors from the public, private and academic sectors.

While these are long-known attributes of the higher education system, their quality, intensity and impact on the creation of new knowledge varies widely across countries and regions. The importance of the Knowledge Triangle concept is that it emphasizes the contribution of education to research and to innovation creation. While traditional policies have focused primarily on education's contribution to enriching human capital and research's contribution to the advancement of science, more recent decades have witnessed a surge of policy interest in the innovation function of universities. Hence, most headline policies have tended to focus on increasing the contribution of research to innovation, highlighting legislative reforms such as the Bayh-Dole Act in the United States and the creation of technology transfer offices and other interfaces between university research and private sector innovation [*Pascoe, Vonortas,* 2014].

There is a wide variety of channels for knowledge transfer and commercialization by universities [*Kergroach et al.,* forthcoming]. Drawing on the OECD [OECD, 2013, Table 1.1] and the US National Academies [NRC, 2010], one can list the following:

Traditional, Core Channels of Knowledge Dissemination

- *Publications.* Published papers, books, conference proceedings, reports.
- *Conferencing, networking*. Professional conferences, informal relations, working or casual contacts.
- *Consulting*. Research or advisory services by public/academic researchers to industry. One of the oldest and most widespread channels.
- *Industry hiring, student placement*. May be institutionalized to include internships, joint supervision of theses, collaborative research.
- *Development of standards*. Documents based on various degrees of consensus defining things such as terminology, measurement, testing, and interface standards.
- *Company formation by students and recent research-trained alumni*. The attention given to this channel has intensified.

Less Traditional, "Third Mission" Channels of Knowledge Dissemination (Commercialization)

- *Collaborative research*. Universities and companies undertake joint research projects. The research may be co-financed.

- *Technology research partnerships*. The formal creation of partnerships with a varying number of members such as research corporations; the formation of long-term research agreements; and public-private partnerships.
- *Contract research*. Industry commissions research in pursuit of a solution to a specific problem; this activity is distinct from most types of consulting.
- *Patenting and licensing*. The bread and butter of technology transfer offices. This became popular only relatively recently. It ranks low on the agendas of universities and industry but high on those of governments.
- *Company spin-offs from academic research*. It has only recently attracted the attention of policy makers. It is an infrequent phenomenon, certainly when compared to company formation by students and alumni.

The dividing line between these two categories is blurry and arguably artificial. One can always find examples of the second category existing far back in universities' history. It must be stressed that:

1) Knowledge transfer from universities and PRIs has always been present.
2) Knowledge transfer occurs in both directions, permitting mutually beneficial relationships due to the sharing of research findings and business information.
3) The traditional channels of knowledge transfer remain the most important (by far) to date and will continue to be so in the foreseeable future.
4) There is a sharp distinction between the two categories of channels in the sense that the entries in the second category much better fit the modern terms of "knowledge commercialization" and "academic entrepreneurship".

The Bayh-Dole Act was intended to facilitate technological innovation in the United States by standardizing intellectual property ownership of inventions resulting from federally funded research. Until then the government retained title to such inventions regardless of who performed the research. Access to research was typically provided through non-exclusive licenses. Public agencies and departments had no fewer than 26 different policies regarding the use of federally funded research [*Schacht,* 2009]. The Act was meant to replace the bureaucratic red tape and enhance knowledge utilization with a single national policy, allowing the inventor to retain intellectual property ownership.

The Bayh-Dole Act became one of the most widely acclaimed pieces of legislation, versions of which have been widely adopted around the world. Nevertheless, it is the creation of spin-off companies that has recently attracted the most attention with respect to knowledge dissemination from HEIs in the context of their third mission. Proponents argue that the genetic characteristics of such firms in the early years following their foundation will tend to reflect the competencies and interests of the company founders, resulting in companies much more closely connected to the knowledge economy and high value-added activities [*Gokhberg et al.,* 2016]. Questions that remain open include: (1) Is this conjecture actually true? Do university spin-offs have better chances of survival than other newly founded companies? Are they relatively more successful (grow faster) than other such companies?

The articles in this special issue visit the Knowledge Triangle from various perspectives and in various national/regional contexts, painting the picture of a rich milieu that delineates and supports the three aforementioned functions of universities.

The paper by Wolfgang Polt and Maximilian Unger provides a conceptual discussion that lays out the definitions of the Knowledge Triangle concept and its connection to other frameworks such as the national innovation systems. It stresses a systemic approach to the *orchestration* of knowledge creation and innovation processes by relating the three spheres of education, (academic) research and knowledge creation, training and (business) innovation. The paper provides a rich picture of the actors in the Knowledge Triangle, the role of universities, public research institutes, public authorities and the private sector, as well as the relevant policy instruments.

Closely related, the paper by Mario Cervantes takes a broad view of the Knowledge Triangle across OECD countries. It goes to the fundamentals of the concept, its roots, its usefulness in underwriting policy. It stresses that HEIs are diverse actors with diverse missions and that the "optimal" structure of HEIs in relation to innovation is likely to be country-specific. In other words, there is no single model of HEIs or of the Knowledge Triangle. Despite this diversity, it turns out that education, research and innovation activities at HEIs are highly concentrated (intense) across OECD countries, reflecting a combination of historical and scale factors, government policies, and institutional policies. These notwithstanding, concentration could simply reflect the non-egalitarian academic ethos of "winner takes all". The article then discusses a number of broad changes affecting STI policy and HEIs.

In their paper, Chataway, Parks and Smith ponder how open science may affect university-industry collaboration. This is a rather relevant subject given the increasing pressure to make science "open", including pressure from funding organizations. Although the required degree of openness varies and what exactly is a more open approach is open to interpretation, there is now a near consensus that, at the very least, open access must apply to published research results. Furthermore, some funders increasingly require access to research data as well. Other stakeholders call for more transparency and less duplication in research. The article outlines evidence supporting the argument that open science presents a set of convincing alternatives to the traditional models of research activity and conventional metrics for academic success and career progression. The paper also tries to set out key questions underlying the rate and direction of change in open science. The authors argue that the impact on industry-university collaboration will depend on several key decisions made by stakeholders and policymakers.

The remaining four articles deal with aspects of the situation in four different countries. The paper by Natalia Shmatko and Galina Volkova analyzes the motivation patterns of researchers based on data from the Russian section of the international project "Careers of Doctorate Holders". It investigates the evolution of this motivation during different career periods. The eight most common patterns of motivation are identified as the basic motivational structures for researchers. Most of these patterns relate to the focus on the creative and innovative nature of scientific work. The second important component is independence and relative autonomy, typical for research activity. Economic motives are rarely important when choosing an academic career; however, they play an instrumental role in the actual implementation of research. The paper argues for the creation of adequate conditions so that scientists can realize their full research potential and recommends the creation of measures to improve scientists' reputation.

The paper by Perez Vico, Schwaag Serger, Wise and Benner examines Knowledge Triangle configurations at three Swedish universities. The article states that although the Knowledge Triangle remains a priority for universities, explicit national policies addressing the integration of education, research and innovation are absent, with the responsibility of integration falling on universities themselves. The authors observed the significant diversity in how knowledge principles are orchestrated across universities. The three functions are handled more or less separately, with weak coordination from university management teams. Tensions emerge as the responsibilities of operationalizing the Knowledge Triangle falls on individuals who sometimes lack the appropriate mandate and resources.

Finally, the last two papers by Anra and Yamin and by Eghbal, Hoveida, Siadat, Samavatiyan, and Yarmohammadian, respectively, look at faculty incentives and behavior at Jambi University in Indonesia and three public universities in the city of Isfahan, Iran. They find strong effects of organizational culture on performance. Moreover, the improvement of human capital management processes can lead to faculty members' perceptions of increased organizational justice and, ultimately, improved research performance.

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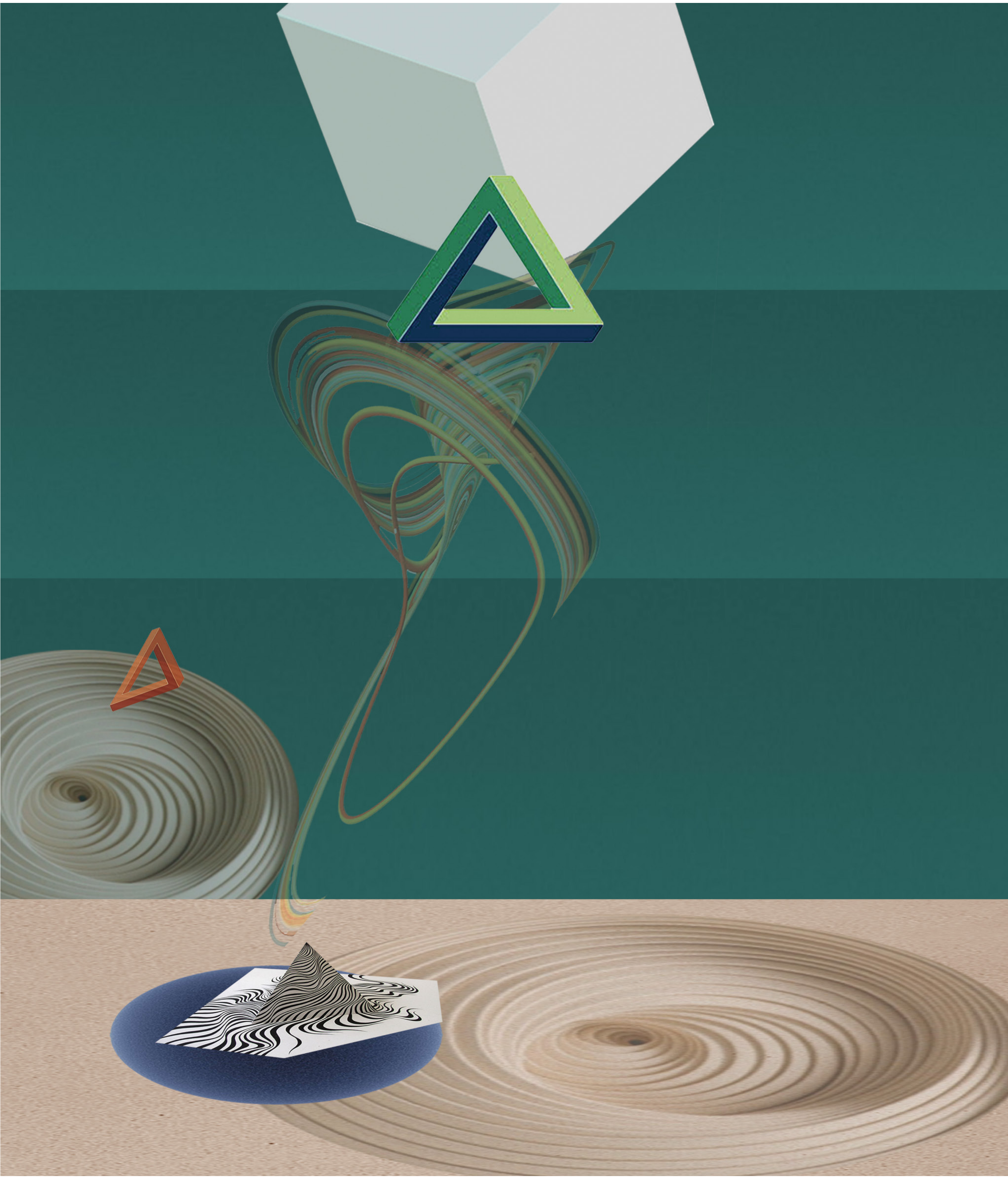
STRATEGIES



The Knowledge Triangle between Research, Education and Innovation – A Conceptual Discussion

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Abstract

This paper discusses the concept of the knowledge triangle (hereafter KT), as it has gained importance in recent years as a framework for innovation policies especially in OECD and Europe. The concept has gained popularity because it emphasizes an integrated (systemic) approach to the interlinkages between research, education and innovation. In this article, we highlight the key features of this concept and try to contextualize it with other concepts, at times overlapping, at others complementary, such as the "third mission", "triple helix" (or in an extended understanding, the "quadruple helix"), "entrepreneurial" or "civic" university models and "smart specialization". Against this background we seek to analyze the roles, rationales and challenges of different actors that are involved in activities relating to each of the three areas of the triangle. Actors are first and foremost higher education institutions (HEIs), public authorities, research and technology institutes and private sector companies.

Keywords: knowledge triangle; triple helix; entrepreneurial university; civic university; third mission; higher education institutions (HEIs); public research institutions (PRIs); private companies; research; education; innovation; STI policy.

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Introduction to the KT concept

The concept of the KT, unlike more straightforward models of knowledge transfer and the commercialization of scientific research, takes a more systemic approach to the *orchestration*[1] of knowledge creation and innovation processes by linking the three areas of (academic) research and knowledge creation, education and training, and (business) innovation. In the past, other concepts were developed, stressing individual actors and dimensions, i.e., *third mission*, *entrepreneurial university*, and the *triple helix*. These concepts are briefly described in Table 1.

These concepts offer different approaches both for analysis and policy, but they also have some common and overlapping features. Hence, it is necessary to elaborate on the differences between them: for example, the KT concept covers much the same ground as the triple helix concept. However, whereas the KT employs an *activity*-oriented approach to linking the spheres of education, research and innovation, the triple helix considers the *actors* in the respective national or sub-national innovation systems as a starting point. Hence, the concept of the KT is a functional model of interaction among these three areas with a specific emphasis on the following channels of interaction:

- *Research and Education:* interactions in this channel are reflected for example in the geographical and sectoral mobility of graduates, postgraduate training programs, fundamental and applied research as the foundation for research-based teaching and measures to improve skill-matching between companies and graduates.
- *Research and Innovation:* here, the support and intensification of the transfer of knowledge comes into focus, for example via i) public-private partnership models (e.g., clusters, science parks), ii) the commercialization of publicly funded research (intellectual property rights — IPRs), iii) contract research and development services from universities for the industrial sector, iv) university spin-offs and academic start-ups, v) knowledge and technology transfer offices (TTO), vi) incubators, vii) open science/open innovation platforms.
- *Education and Innovation:* Collaboration between actors is evaluated by considering the support for the development of an entrepreneurial culture (entrepreneurial spirit) in the framework of (academic) training programs (e.g., industry-focused doctoral programs) and the formation of appropriate competencies (business plan development, management, etc.).

As Markkula [*Markkula,* 2013] states: "*The Knowledge Triangle concept relates to the need to improve the impact of investments in the three activities — education, research and innovation — by systemic and continuous interaction.*" Hence, the KT can be defined as a set of actors, policy spheres (education, research, innovation) that span the space for collaborative activities (see Figure 1).

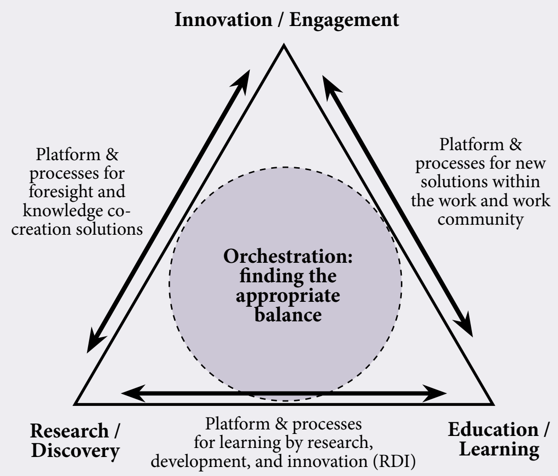
The concrete manifestation of these interactions in the KT is very much dependent on the respective structure of the national or regional innovation ecosystem [*Lundvall,* 1992; *Edquist,* 1997; *Jackson,* 2011]. Hence, the KT concept surely can be subsumed under the category of "systemic innovation concepts". It has to be noted, however, that the KT concept is not meant to supplant any of the aforementioned concepts, some of which have already found their way into policy strategies and documents and which may already be well-anchored in the STI policy of a country or in the strategy of an institution. Primarily, it may serve as a common frame for the analysis of different policy frameworks being used in different countries. In the policy approaches of some countries, KT is also used as an "umbrella framework" to include all other approaches.

Table 1. **Complementary concepts of innovation system governance**

Name of the concept	Description
Third mission [OECD, 2015]	Calls for an extended understanding of HEIs mission, referring to their societal and cultural relevance and their role as provides knowledge transfer and commercialisation activities. It has been taken up in government as well as institutional policies in many countries in recent years.
Entrepreneurial university [*Etzkowitz,* 1983; *Etzkowitz et al.,* 2008; *Foss, Gibson,* 2015].	Whereas the "third mission" serves as a summarizing term for an expansion of universities core missions, the concept of the entrepreneurial university prioritizes the entrepreneurial activities of universities, mainly relying on their research activities, and second, a new management paradigm for the provision of universities' tasks.
Triple helix [*Etzkowitz, Leydesdorff,* 2000; *Leydesdorff,* 2012; *Ranga, Etzkowitz,* 2013].	Highlights the importance of a systemic coordination of actors from the higher education and business sector with public authorities to contribute to innovations and knowledge based growth]. In its extended understanding, the "quadruple helix", also incorporates actors from the civil society, such as citizens, NGOs, consumer organizations, etc.
Source: compiled by the authors basing the abovementioned works.	

[1] Wallin [*Wallin*, 2006] defines orchestration as: "*the capability to mobilize and integrate resources for the purpose of providing an offering to a customer and simultaneously create value for the customer, the orchestrator, and the network members involved. The orchestrator considers the constraints, based on which conversations are nurtured, to define and execute the purposeful resource allocation to create, produce, and provide the customer with the offering*".

Figure 1. **The Knowledge Triangle of Education, Research and Innovation**



Source: [*Sjoer et al.*, 2011].

In the following sections, we present and discuss i) actors, ii) transfer mechanisms and iii) policy paradigms related to and involved in the concept of the KT with an emphasis on the following main questions:

- *Which types of actors are engaged in the KT?*
- *What are the challenges in terms of governance approaches towards the links and interactions between the three corners of the triangle?*
- *What are the characteristics of the policies that may affect or support the design of the KT?*

In the final sections, we present some tentative conclusions regarding the usefulness of the KT concept as a policy tool, and as a socioeconomic model or guiding principle for the development of academic institutions.

Main actors in the Knowledge Triangle

Higher Education Institutions

Higher education institutions (HEIs) are the backbone of the KT, first because they provide key inputs for each of the corners of the KT and second because they often institutionally incorporate KT dimensions into their internal organization and mission.

An assessment of HEIs' contribution to the different corners of the KT has to take into account the great variety of institutions in this sector regarding their mission to perform education and research, their ownership structure and institutional autonomy, their mandate to engage in third-mission activities beyond research and therefore their role in the national/regional innovation system.

In a broader definition, higher education institutions are typically classified as i) universities, performing research and research-oriented education and ii) universities of applied sciences (UAS) or university colleges, typically providing education focused on a particular profession (in many cases, centered around a narrow speciality) and, typically in a limited amount, applied research. Other types of institutions in this vein include academies of science offering doctoral degrees and higher education institutions that serve specific professions, e.g., nursing schools, pedagogical colleges or business schools, which may often focus on specific educational levels such as Bachelor's or Master's degrees. The importance of the different types of institutions varies between countries.[2] Variety does not exist only between different types of institutions, but also between similar institutions. For example, some key aspects of these differences include research and educational topics, endowment with resources, the organizational structure and the effectiveness of internal governance mechanisms as well as the interactions with other critical stakeholders such as institutions, companies and society as a whole. Thus, recognizing this considerable degree of diversity in the higher education sector, it becomes clear that policies aimed at improving HEIs' engagement in the KT have to flexible enough to be calibrated to the individual characteristics of a given institution.

[2] For example, see the European Tertiary Education Register (ETER): https://www.eter-project.com/about/eter

Compared with other types of higher education institutions, by their nature, universities tend to provide services feeding into at least two corners of the KT, tertiary education and research. They integrate these two spheres in line with a focus on research-oriented education. A change in the role of universities and an expansion in their range of activity is determined by several key trends:

- A trend towards the decentralization of governance and the greater autonomy of institutions, combined with shifts to funding schemes with a greater emphasis on performance and competition, has affected universities' ability to autonomously allocate resources, set strategic targets and shape their unique profile in research and education;
- Increased international collaboration facilitates, on the one hand, the exchange of knowledge and experience in research activities and best educational practices, on the other, however, this leads to increased competition between institutions for talent researchers and students;
- The expansion of the types of key university activities beyond education and research, has influenced innovation strategies, financing schemes and relevant policies, as well as the realization of the third mission and the "entrepreneurial university".

Given the dual move towards increased autonomy and accountability for HEIs in most countries, many countries have deliberately acted to strengthen and formalize the image of HEIs as socially significant establishments engaged in the transfer of knowledge. In Sweden, for example, the "third mission" has been officially recognized in the Higher Education Act since 1997 [OECD, 2015]. The emerging importance of the knowledge-based economy also calls for a new understanding of the key tasks of universities. For example, Foss and Gibson [*Foss, Gibson,* 2015] identify two major types of "entrepreneurial" activities of HEIs:

- *Entrepreneurial education* is understood as the fostering of an entrepreneurial spirit in students and graduates as part of the university's academic programs, e.g., by offering specific courses, joint labs and platforms for co-creation with industry actors and the implementation of inter-sectoral exchange programs.
- *Entrepreneurial activities* involve the creation of spin-offs and academic start-ups, the production of IPRs and engagement in collaborative research. *Academic entrepreneurship* involves the development of support structures for commercialization such as technology transfer offices (TTO) or industrial-liaison offices (ILO).

The concept of the entrepreneurial university serves as a basis for a partnership between the government, business and academic sectors. An emphasis was put on the idea that universities must consider entrepreneurialism a key value of their organization. This involves the transformation of universities' management and organizational structures and mechanisms, which leads to universities becoming autonomous and strategic actors in the innovation system. This institutional transformation includes three major pillars [*Scott,* 2014]:

- The regulative pillar involves the establishment of a legal framework, governance mechanisms and a monitoring system;
- The normative pillar involves the realization of university functions in accordance with expectations placed on them, which is dominated by societal values, the surrounding environment, conventions and standards;
- The cultural-cognitive pillar involves rooting the entrepreneurial role of the university in the behaviour of individual researchers and HEI teachers.

Thus, the role of entrepreneurship in university activity depends on several institutional factors: institutional autonomy, the allocation of funding streams, governance mechanisms and the surrounding entrepreneurial climate. Furthermore, a distinction can be made between the exogenous (top-down) and endogenous (bottom-up) factors that shape universities' transformations into entrepreneurial institutions [*Etzkowitz et al.,* 2008]. Exogenous factors include external shocks, such as the 2008 economic crisis and subsequent grand societal challenges, which then called for knowledge-based and sustainable solutions. This has endowed universities with the key role as partners in overcoming these challenges by creating these new solutions and innovations. The endogenous factors include internal transformations of the institutions themselves, e.g., of their organizational structure or strategic targets, or the bottom-up coordination of individual departments' provision of university services, such as conferences.

Given the diversity of exogenous and endogenous factors that affect university activities, it becomes clear that entrepreneurial universities can and do have a variety of characteristics. Bronstein and Reihlen [*Bronstein, Reihlen,* 2014] developed a typology of these different characteristics based on a meta-analysis of the structural features of institutions, such as governance and organizational models, human resources, financial resources, infrastructure, missions, strategies, location and environment. They identified four different university archetypes — *research-preneurial*, *techni-preneurial, inno-preneurial,* and *commerce-preneurial* (Table 2).

Table 2. **Classification of entrepreneurial universities**

Orientation	Main characteristics	Examples
Research-preneurial	• Focus on the creation of new knowledge and research excellence • Traditional academic organizational structures (departments, faculties) • High degree of public funding (basic and competitive funding schemes) • Often host large research facilities • Strive to find external funding, which motivates these universities to implement socially oriented programs, the development of research and commercialization. Their resources include (joint) research centers and special divisions responsible for ILOs and TTOs	• Stanford University, US • Technical University of Munich, Germany • University of California at Berkeley, US • Universidad Católica, Chile
Techni-preneurial	• Focus on applied research but still mostly publicly financed; • Strong ties to relevant industries, both at an institutional level and at the level of individual staff members, as direct providers of knowledge • Focus on inter-sectoral mobility (tailor-made academic programs in conjunction with businesses, entrepreneurship education, on-the-job training) • High degree of regional embeddedness	• University of Joensuu, Finland • University of Waterloo, Belgium • Hamburg University of Technology, Germany
Inno-preneurial	• Focus on innovative services and business solutions • Flexible structures that adapt to market characteristics; • High degree of private sponsoring, e.g., for professional schools • Incentive schemes emphasizing innovation and entrepreneurialism • Knowledge transfer and commercialization activities, including business and consultation services • Typically located in large urban areas and clusters	• University of Joensuu, Finland • University of Waterloo, Belgium • Hamburg University of Technology, Germany
Commerce-preneurial	• Focus on the commercialization of innovations and marketable products in specific high-tech sectors • Strong links with industry due to joint projects and joint ventures • Entrepreneurial facilities such as business units, incubators and technology parks are core parts of university infrastructure • High importance of market-oriented project funding; • Managerial approach to governance • Emphasis on public relations and marketing	• Twente University, Netherlands • Bandung University of Technology, Indonesia • Waseda University, Japan

Source: compiled by the authors using [*Bronstein, Reihlen,* 2014].

Though one might be able to identify examples that serve as perfectly fitting prototypes for each of these archetypes, most universities actually could be categorized as more than one type due to their mostly multifunctional roles stemming from path dependencies in their development, governance structures, environment and culture.

Another important dimension that has recently gained traction puts an emphasis on an extended understanding of HEIs' social role, resulting in "civic (or engaged) universities" (see, e.g., [*Goddard,* 2009; *Henke et al.,* 2015]). The fundamental starting point here is that HEIs are seen as providers of public goods, hence the results of research and education should not solely be assessed in terms of quantity and excellence, but in terms of their social significance and relevance. This especially includes the potential to contribute to the solution of societal challenges such as ageing populations, sustainable energy production, smart mobility solutions, etc. Another core function of the civic-oriented model is the university's contribution to social inclusion by striving to provide equal educational opportunities to all strata of society. Typically the civic engagement of HEIs has a strong place-based dimension, with an emphasis on their direct impacts on their regional environment (policy strategies based on location will be considered in a later section). Hazelkorn [*Hazelkorn,* 2015] provided some examples of how the "civic university" can contribute to the activity of all three axes of the KT (Table 3).

Both concepts of "entrepreneurial" and "civic" universities call for an extended understanding of the role of HEIs beyond research and teaching, which also requires relevant organizational transformations. Nevertheless, there are also contradictions between these two models given that the focus on entrepreneurship, modernization and a pragmatic allocation of resources based on commercial results may lead to a breakdown of the university's social goals. These targets are often intangible in the short term. On the other hand, an innovative and flexible approach could include both the entrepreneurial and civic models, reaping additional benefits by using creative resources for the development of new solutions.

Public Research Institutions (PRIs)

In a number of countries, public research institutions (PRIs) are important actors in public sector research. Over the course of the last few decades, their share of domestic R&D spending has been on the decline in many OECD countries, mainly at the expence of higher education institutions [OECD, 2011b]. However, they remain critical actors in some national innovation systems, as dedicated research providers of unique, niche research for commercial application. Together with companies, they perform research in specific

Table 3. **Civic universities' roles within the KT**

KT axis	Description
Education – Research	Research-informed teaching that engages students in real, relevant research projects in the classroom based on the university's expertise in order to contribute to the solution of complex, comprehensive and interconnected problems in cities or regions
Education – Innovation	Students' involvement in projects with real public or private clients, allowing them to apply their specialist skills and receive course credits for their work, while engaging in the teaching process, the wider community also reaps benefits from the student's work[3];
Research – Innovation	Focus on problem-solving, use-inspired research that makes a real impact on people's lives
Source: complied by the authors using [*Hazelkorn*, 2015].	

fields or implement long-term strategic projects, such as those dedicated to space exploration. Due to the great diversity of institutional types among OECD countries, typologies of PRIs must be considered with care. The OECD Innovation Policy Platform provides a useful, but broad, characterization of the "ideal" types of PRIs (see Table 4).

This broad typology illustrates why PRIs must be considered critical actors in the KT. They act at the intersection between public HEIs and the private sector, performing specialized applied research and providing career opportunities for researchers from specific fields, sometimes beyond a given university's purview. In addition, PRIs sponsor research that is not always market-oriented. Whereas Table 4 takes an *ownership* perspective in the classification of different types of PRIs, Table 5 considers more *functional* aspects of PRIs, highlighting several knowledge transfer channels. This concerns where PRIs might be engaged along the three axes of the KT, especially the ties between research and innovation, academic institutions and PRIs, and those between education and innovation, due to, for example, the mobility of researchers.

Private Companies

The business or private sector as a component of the KT framework significantly differs from public institutions and innovation policymakers. It is commercial interest, rather than some other social or political vision, that is decisive in whether or not private companies might interact with the public and semi-public sectors (however, the notable impact of philanthropic activities from the private sector should not be overlooked).

These interactions can take place through different channels. A key factor is the mobility of skilled personnel with all levels of education, who make up the foundation upon which companies' innovation potential is built. Second, there is also the research by either public universities or PRIs, which directly or (in the case of basic research) indirectly could be converted into innovations (see [*Jaffe,* 1986; *Karlsson, Andersson,* 2005]).

Table 4. **Typology of Public Research Institutions (PRIs)**

Type	Characteristics	Main functions
Mission Oriented Centers (MOC)	Owned and sometimes run by government departments or ministries at the national or sub-national level (e.g., NASA, USA)	Perform public research in certain thematic areas; support public decision-making
Public Research Centers and Councils (PRC)	Large multi-disciplinary organizations with a significant share of public R&D funding (e.g., Max-Planck-Gesellschaft, Germany)	Perform (and sometimes fund) public fundamental and/or applied research in several fields
Research Technology Organizations (RTO)	Often in the semi-public sphere (although some are owned by governments); private non-profit organzations. Also known as industrial research institutes. (e.g., Fraunhofer Gesellschaft, Germany; Netherlands Organization for Applied Scientific Research (TNO))	Provide links between public sector research and private innovation activity; knowledge transfer to business sector and society
Independent Research Institutes (IRI)	Semi-public; exist in various legal forms with varying ownership structures (e.g., run by HEIs); often founded on a temporary basis at the boundary between the public and the private sector research (Competence Centers for Excellent Technologies (COMET), Austria)	Perform basic and applied research focused on specific issues or problems, research mostly performed under the aegis of joint HEI projects with the public and private sector
Source: compiled by the authors using [OECD, 2011a].		

[3] One example in this vein is Finland's Technical University of Tampere. It hosts the "Open Innovation Platform Model", which strives to practically implement IT solutions and involves students and companies, secondly, the Campus Arena, which aims to engage companies and students in joint projects.

Table 5. **Functions of PRIs**

Function	Example of activities	Rationale
Fundamental/ strategic research	• Fundamental research in particular in strategically important areas, e.g., defense, security, nuclear energy, public health, etc. • Long-term research	• Improbability that enterprises or universities would undertake this work with a sufficient breadth/depth of study, inter-disciplinarity, and appropriate continuity • Need to combine basic and applied research to ensure knowledge integration, i.e., bring together knowledge from own's own research and other sources • Complementarity with university research (link-function) • Scale of investments required for critical mass (personnel, facilities, equipment, etc.) • Public security interests (in strategic or sensitive areas) • Provision of specialized training and skills (perhaps a benefit rather than a motivating factor)
Technological support for economic development	• Contract research services for businesses • Collaborative research with industry • Long-term, foresight-oriented technological research (speculative research) • Technological "expansion": support diffusion and adoption of existing technologies • Market intelligence services, • Technology matching services	• To compensate market imperfections related to costs and risks • To accelerate, broaden and expand technology diffusion
Information support for public policy	• Fundamental and preventative research, focused on environmental policy, public health, food security and safety, sustainable development • Pre-emptive policy design and impact analysis • Monitoring of the implementation of policy concerning, e.g., pollution, seismic surveys • Expert assessments	• Impartiality (including the need to separate monitoring and control functions from advocacy functions) • Unbiased broker of policy alternatives • Need for resource-/time-intensive expertise (i.e., more than occasional or one-off expert assessments) • Responsibility and accountability
Technical norms, standards	• Pre-normative research • Implementation of monitoring, e.g., metrology • Certification of products (and accreditation of certifiers)	• Impartiality • Public security based on independence
Construction, operation and maintenance of key facilities	• Large infrastructure (e.g., accelerators, research reactors, botanical gardens, large computing facilities) • Large, unique, and perhaps dangerous collections of research samples • Large, long-term data collection	• Potential market failure: "Cost beyond the resources of other players" • Security and safety (physical concentration of infrastructure, accountable management)
Source: compiled by the authors using [EURAB, 2005; EARTO, 2005; *Pielke,* 2007; *Gulbrandsen,* 2011].		

The way in which and the degree of the intensity with which private companies might engage in collaboration with the public research sector and universities determines the contribution companies make to education and R&D. Although the literature usually focuses on the contribution of HEIs to innovation and private sector activities, this overview highlights the various potential contributions and spillovers in both directions. Table 6 presents a list of some direct inputs and indirect spillovers from the private sector, based on indicative examples from case studies carried out as part of the project on which this article is based.

State Authorities

Policymakers consider higher education institutions to be suppliers of competent specialists and participants in national and regional innovation systems. The term "knowledge triangle" gained importance especially as part of the European Commission's policy strategies, according to the targets formulated in the European Union's 2020 Strategy for Smart Sustainable Growth [European Council, 2010]. According to this strategy, effective links between research, education and innovation are considered a key prerequisite for tackling societal challenges. In 2009, the Council of the European Union announced: "*… [the] need for improving the impact of investments in the three forms of activity — education, research and innovation — by systemic and continuous interaction*" [Council of the European Union, 2009]. Therefore, the KT is not a finite concept, but should serve rather as a guiding principle, directing the attention of actors to creating productive links between the education, research and the business sectors. Policies in line with this approach should promote the expansion of academic cultures beyond research excellence and teaching alone towards innovation and the development of solutions for socioeconomic challenges. Besides applied research and commercialization activities, universities should contribute to the formation of such assets as relevant and diverse competencies (including soft and entrepreneurial skills) and an innovative and entrepreneurial spirit. In their *Agenda for Europe's Higher Education Systems*, often referred to as the "modernization agenda", the European Commission calls for a greater variety of study models to provide flexible and personalized learning opportunities and the improvement of specialist training programs at all levels, including doctorate, so that graduates would

Table 6. **Spillovers from private sector to HEIs' research and educational activity**

Direct contributions to research	• The provision of funds for R&D and innovation projects of public institutions. Private funds are an increasing source in university budgets in many OECD countries, influencing university potential and shaping their profiles. Investments are made via competitive research grants and prizes, the hire of well-known professors, or through competitive programs, run either by the company itself or by intermediaries such as private foundations. • Co-financing or other involvement in government initiatives (joint R&D projects, clusters, etc.) • Participation in the basic funding of HEIs, e.g., via donations or investments in research infrastructure
Direct contributions to education	• Grants and scholarships for students • Collaboration with HEIs in terms of hosting students as part of their professional education, e.g., via internships, the co-supervision of research thesis papers, or part-time employment of young researchers on a collaborative basis as part of, for example, an industrial doctoral program, specialized colleges or European programs such as the Marie-Sklodowska Curie Actions • Involvement in the development of curricula • Guest lecturers • Participation in the basic funding or even foundation of HEIs, especially of universities of applied sciences or institutions with professional or technical colleges, according to specific needs of companies in a certain location (e.g., technical universities in the Netherlands or "new universities" in Sweden)
Indirect spillovers affecting research	• The creation of an entrepreneurial ecosystem around HEIs in which there are a dynamic variety of companies, either large multinationals or small and medium enterprises (SMEs), is crucial for the university's and individuals' attitude towards engaging in entrepreneurial activities. This is motivated by a kind of entrepreneurial spirit, the existence of opportunities for the commercialization of know-how and the capitalization of start-ups, with an explicit or implicit focus on businesses' needs. • Companies' needs may implicitly influence the research profile of HEIs, i.e., by pointing toward specific challenges and future needs that demand solutions. • Companies act as an absorber and user of knowledge produced by the public sector, which may help them when justifying the need for public funds in R&D
Indirect spillovers affecting education	• Demand on the labor market serves as indicator for the development and relevance of academic programs • Some graduates may still be connected with their alma mater, e.g., via alumni associations or as donors, and serve as a starting point for the future networks of young graduates

Source: compiled by the authors.

be more in demand and ready to meet the needs of a dynamic and changing labor market [European Commission, 2011].

Due to the great heterogeneity of the formal responsibilities of governmental and administrative entities, it is impossible to classify the role of public authorities in the KT in a single, all-encompassing framework. Differences exist, for example, in the governance and financing of higher education institutions, depending on whether this is anchored at the national or sub-national level (Germany and Spain can serve as examples of countries with a highly decentralized system). Other differences occur depending on the extent of institutional autonomy and the degree of automatism in funding schemes (according to the application of formula-based or contractual schemes, for more, see the next section).

Differences in approaches to innovation policy may emerge depending on whether or not innovation is among the formal responsibilities of a certain ministry or whether innovation is considered a guiding principle for coordinating various concepts, funding schemes and institutional targets that are among the responsibilities of several ministries. This is increasingly relevant given the challenge-oriented approach to policy formulation. This type of policymaking takes a topic- or technology-oriented perspective (e.g., climate change, energy security, mobility, etc.) as opposed to the activity-related approach that is used in the KT framework (e.g., collaboration in research, personnel mobility, etc.). Earlier such concepts focused on technological sectors, while new horizontal approaches to determining priorities focus on social needs and challenges (e.g., the EU's formulation of the "grand societal challenges" and their integration into the current research framework program, HORIZON 2020). These mission- or challenge-oriented approaches call for the integration of actors and policies along defined priorities. Often, they focus on real educational issues, such as the need for a focus on math-information technology-natural sciences-technology (MINT) or the integration of innovations as a guiding principle for the provision of education at all levels (e.g., the Dutch Technology Pact). Hence, the KT will have different configurations depending the institutional actors and responsible state authorities.

That said, in general, the state authorities (ministries, regional and local administrations) fulfil the following roles in the KT:

- Provision of a legal and regulatory framework for public research, education and innovation activity based on the delegation of duties to the relevant agencies and for the formulation of norms, standards and regulations for businesses;
- Provision of funding for higher education, public sector and private sector R&D and innovation activities both directly as well as through funding intermediaries such as councils, state agencies and foundations, they can also to this through indirect stimulus mechanisms like tax incentives (*supply side policies*);

- Encouragement and support of innovations by creating demand for them, i.e., innovation-oriented public procurement;
- Absorption and use of highly skilled human resources, research and innovation outputs;
- Definition of thematic or technological priorities that serve as medium- to long-term guiding principles for funding and planning public and private sector activity [*Mazzucato,* 2013].

In attempting to integrate activities within the KT, public sector administrations are confronted with a variety of challenges [*Markkula,* 2013, p. 18]:

- Embedding entrepreneurial culture throughout the higher education institution
- Involving students as co-creators of knowledge and as part of the innovation system
- Creating rich learning environments for talent development
- Quality assurance and recognition of the need to develop new skills and competencies
- Adopting an interdisciplinary approach to higher education research, and the development of policies targeting, for example, the EU's "grand societal challenges"
- Developing academic talent and skills
- Internationalization as a way of improving institutional practices
- Implementation of flexible management models
- Life-long learning, inter-sectoral mobility
- Embedding evaluation and monitoring systems to determine the impact of activities related to the KT in university strategy
- Smart specialization as a policy focus for KT activities
- Adopting a long-term vision for change at the institutional level
- Incentives and funding structures
- Engaging with the national policy environment across the areas of research, education, enterprise and innovation.

The increasing internationalization of research as a consequence of the globalization of value chains for goods and services and the anticipation of challenges that call for global cooperation (climate change, energy production and resource management) also calls for a new way of coordinating relevant and pressing policies across countries. This model is already used by the Knowledge and Innovation Communities (KIC) of the European Institute for Innovation and Technology (EIT).[4]

Governance models and policy tools for the support of knowledge triangle activities

Industrial Policy, Education, and Innovation Policy are often treated as separated policy fields, which may cause "silo-thinking" (i.e. thinking within the narrow confines of the own institution, e.g. a ministry) on the level of state authorities. The KT approach seeks to remedy this shortfall, calling for an *integrated* approach to the three aforementioned spheres to foster economic development. We will consider the relevant mechanisms in educational policy, the tools for developing ties between research and industry, as well as those for performing expert evaluations as part of the KT in the following section.

Funding and management of Higher Educational Institutions

As key actors in the KT, higher education institutions play a crucial role in shaping it. The design of governance structures and funding mechanisms is an important determinant as to how higher education institutions may position themselves within the KT, as they provide both incentives for and barriers to individual researchers as well as the institution as a whole. Several developments took place over the course of the past two decades in many OECD countries that directly impacted HEIs' engagement in KT activities. These developments include changes in the regulatory framework as well as shifts in the steering and funding mechanisms of the state authorities, namely:

- An increase in HEIs' institutional autonomy, regarding the distribution of funds, choice of research partners, recruiting & HR, the development of curricula, etc.
- The introduction of performance-based funding schemes for the allocation of basic public funds including contracts, agreements, formula- and indicator-based schemes.
- An increase in external (competitive) funding from both public and private sources.
- Institutional cooperation and mergers.

These developments will be described in the following section.

[4] https://eit.europa.eu/, last accessed 12.10.2016.

University autonomy and performance-based funding

The rise in universities' autonomy, by means of legal and institutional independence from the state authorities, was accompanied by the introduction of performance-based elements in the allocation of basic public funds to universities in many OECD countries. *"Performance-based funding is to be understood as a type of funding where the (public) budget of a higher education institution varies with the performance of the institution."* [*De Boer et al.,* 2015]. Hicks [*Hicks*, 2012] pointed out six major justifications for the rising importance of performance-based elements:

- the need to incentivize increased productivity;
- the replacement of traditional command-and-control systems with market-like incentives;
- incentivizing a stronger focus on services;
- strengthening the administrative autonomy of higher education institutions;
- contracting services;
- raising accountability for results and outcomes.

De Boer et al. [*De Boer et al.,* 2015] found institutional profiling, i.e., a strategic diversification of the higher education systems based on individual institution's strengths, to be another important result of performance-based funding schemes. Several recent studies surveyed the structure of performance-based schemes in European and OECD countries (e.g. [*Pruvot et al.,* 2015; *de Boer et al.,* 2015; *Hicks,* 2012; *Niederl et al.,* 2011]) finding a great variety in design and targets. Instruments of performance-based funding include formula-based schemes, performance agreements and contracts as well as combinations of these elements. Furthermore, these instruments could differ depending on the point in time at which performance is measured.

Formula-based funding schemes typically use a result-based, retrospective approach, proceeding from past teaching and academic achievements, research and third mission activity, which are assessed by a predetermined set of performance indicators. The productivity of research and third mission activity is often evaluated using the amount of third party funding or cooperation activities. According to the aforementioned studies, frequently used indicator dimensions cover: i) the number of graduates, ii) number of exams passed or credits earned by students, iii) participation in research studies, iv) the social and demographic mix of students, v) average study duration, vi) number of PhD graduates, vii) research productivity, viii) research performance in terms of shares in competitive projects, ix) third-party income, x) university revenue from commercialization activities (patents, license income). In many countries, educational funding is typically provided on the basis of performance indicators (e.g., in Denmark, Sweden, Australia), whereas funding for research is often allocated on the basis of historical path dependencies and only to a smaller extent on performance indicators.

Unlike formula-based schemes, performance contracts or agreements set targets for future performance, usually on a negotiated basis between the relevant ministries and individual universities. These measures can be characterized as being *soft* or *hard* in terms of their effect on funding when targets could not be reached. Performance agreements typically allow for the setting of strategic targets for institutional development other than those that could be directly encapsulated by technical/numerical quality indicators. That is why performance agreements are especially useful tools for expanding HEIs' missions beyond research and teaching activities. Such targets may include: i) the increase of HEIs' social outreach and engagement and the resolution of local problems, ii) the development of a unique institutional profile, iii) the improvement of ties with the business sector and participation in innovation activity, iv) the increase in the international connectivity of national R&D. The difference between the terms "agreement" and "contract" mostly refers to how legally binding a document is. In selecting either mechanism, the authorities decide whether to continue supporting a project and how this support may be extended when announced targets are not met. Although such mechanisms have been used recently in several countries, in most, they are supplements to formula- or historically-based schemes. This is due to their dedicated share of the budget (for most EU countries between 1% and 7% of block grant allocation, according to [*Pruvot et al.,* 2015]), the power of sanction mechanisms, or the focus of those agreements only on specific fields.

Based on an analysis of universities' performance based on international rankings, such as the Shanghai ranking, and patenting activity, Aghion et al. [*Aghion et al.,* 2009] showed that university autonomy and competitive funding mechanisms are positively correlated with university output at both European and U.S. public universities. However, the use of performance-based funding affects not only universities' research and teaching performance, but also determines their innovation potential and therefore their full integration into the KT.

The contributions of autonomy and performance-based funding are decisive for HEIs' participation in the KT in two ways. First, increased autonomy allows more freedom in allocating funds, setting a strategic agenda and developing an HEI's profile. Second, mechanisms for increasing productivity facilitate the development of innovative activity, the commercialization of developments and other "third mission"activities. However, depending on the calibration of such performance-based schemes (the alignment of priorities, financial resources), there is a risk of an imbalance in the support given to various university functions/departments for limited resources. So, a focus on research can lead to a decline in investments in teaching and vice versa. Polt et al. [*Polt et al.,* 2015] in an in-depth analysis of the Danish and Swedish innovation systems, observed that, although innovation is high on the government agenda, especially in Denmark, despite the fact that there is a great deal of commitment to innovation from the university sector, many HEIs feel that this is not properly reflected in the funding made available as it is still focused on education and research excellence. The imbalance between universities' missions may be attributable to mechanisms such as the Swedish "professor's privilege", which allows professors a teaching exemption, permitting them to focus on research alone, while individual researchers are able to retain exclusive rights to intellectual property [*Damsgaard, Thursby,* 2013].

Institutional changes of higher education systems

Along with the increase of a university's autonomy and the introduction of performance-based funding schemes, there were efforts made to consolidate the public research sector through mergers of departments within HEIs themselves as well as mergers between HEIs and PRIs, especially in Northern Europe (e.g., Denmark, Finland) and in France. Such consolidation is thought to lower costs and increase efficiency. However, Pruvot et al. [*Pruvot et al.,* 2015] demonstrated that this is of secondary importance. In fact, the aim to create "critical masses" in areas of research and education, as well as to strive for improvements in quality were identified as the main drivers of these developments. Another observed positive effect is the simplification the public research system in terms of the number of institutions. The merger of the PRIs and universities could help companies improve their access to public research services due to the increased transparency of the institutional landscape and recognition of the great potential offered by ties to the corporate sector [*Polt et al.,* 2015].

Competitive funding for Higher Education Institutions

The change in universities' role in many countries may permit an increase in the share of third-party, i.e., external (non-governmental) funds, in universities' budgets. This, on one hand, is attributable to the rising importance of competitive grants offered by the public sector and its intermediaries. On the other, with universities increasingly engaged in collaborative and contractual research activities, investments increasingly stem from the private sector.

Competitive funding from state authorities has different implications depending on the source of the funds. For example, such schemes can increase excellence in a certain field or improve the link between research and industry. Therefore, they may influence the achievement of targets set down in performance-based basic funding schemes. Depending on the targets of competitive funding, there may be bottom-up or top down-oriented structures for defining thematic areas of fundamental or applied research. Another aspect of competitive public funding programs depends on the recipient, be it a particular project, individual, or be it for the development of institutional ties (e.g., partnership structures with the business sector such as joint labs, centers, etc.) or research infrastructure.

Third party funds from private sources, especially from industry partners, are often used as indicators for a qualitative and quantitative assessment of the transfer taking place between the academic and private sectors. In some countries (such as Denmark, Sweden or the U.S.), private foundations, owned by philanthropic investors or companies, also play an important role in funding R&D and tertiary education. In the framework of the KT, potential conflicts may occur given the different objectives of public and private funders. In some areas, as is the case, in the Danish life science sector[*Polt et al.,* 2015], private money may be the dominant source of funds for university research and also education activities (especially for doctoral programs). Therefore, governments risk losing the authority to determine strategic areas, and, as a result, they have fewer opportunities to determine the research profiles of universities and therefore lose influence over the three spheres of the KT.

Another potential pitfall is that overhead costs connected with competitive funding from both public and private sources are seldom covered sufficiently. With the rise in external investments, a greater share of universities' basic budget becomes dependent on co-financing requirements. This leads to diminished opportunities for strategic action by university management, regardless of the extent of their formal legal independence in the allocation of funds (see e.g. [OECD, 2016]).

Industry-science relations and knowledge transfer

Recent studies have analyzed transfer channels, the freedom of interaction and policy instruments, providing for such knowledge exchanges between academic institutes as well as knowledge transfer from

Table 7. **Knowledge transfer, commercialization channels, and interaction modes**

Transfer channel	Mode of interaction and support instruments
Informal outreach activities	Conference participation
	Formation of social ties and networks
	Inter-sectoral mobility of students and researchers
	Publications
Research & education collaboration	Cooperation in education: firms' participation in the development and implementation of academic programs (e.g., PhD programs, internships)
	Cooperation in research via joint activities and initiatives (research centers, labs, cluster programs, platforms, etc.)
	Research cooperation on project-by-project basis
	Shared research facilities
	Academic consultancy services
	Joint publications
Commercialisation and entrepreneurial activities	Patenting and licensing activities: TTOs
	Public research spin-offs and academic start-ups
Other	Joint development of norms and standards
	Joint provision of recommendations for state policy makers, for example, through research councils or consultations at the EU level (European University Association — EUA)

Source: compiled by the authors using [OECD, 2013; *Mathieu*, 2011; *Perkmann et al.*, 2012].

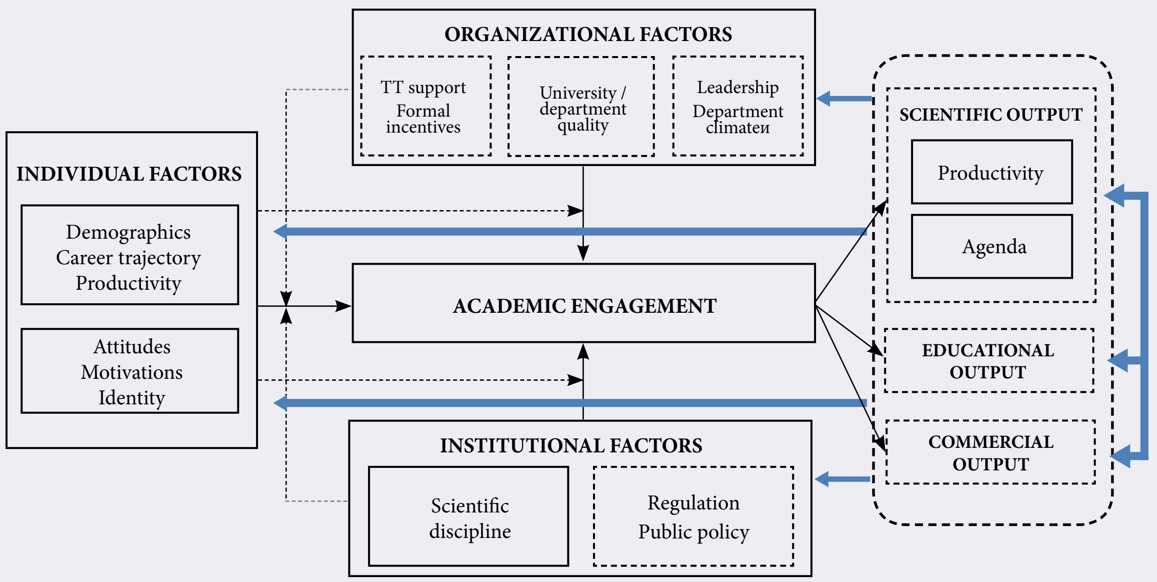
the academic sector to the social and business sectors [OECD, 2013; *Perkmann et al.,* 2012; *Arundel et al.,* 2013; *Mathieu,* 2011]. Some channels are used by third-party actors, such as companies, for the transformation of the products of university research and educational activity into innovations, other channels are the result of entrepreneurial activity by the universities themselves (such as the creation of spin-offs, patenting and other activity generally falling under the term "commercialization"). Furthermore, more informal linkages such as individual networks have also been identified as a key prerequisite for later, official cooperation. Table 7 gives an overview of those commonly identified transfer channels as well as related modes of their formalization and policy support structures.

The importance of these channels and the potential for participation in them are determined by the institutional characteristics of the research and educational sectors, the degree of autonomy and management capabilities of the institution, its departments, faculties and individuals as well as the characteristics of the surrounding environment, which is comprised of potential partner companies and institutions, public funding incentives and political strategies.

The enumerated modes of the transfer of knowledge to society at large are integrated in the KT. Thanks to this interconnectivity in the perspective on industry-science relations spillover effects and externalities between several transfer channels are anticipated. Researchers or faculties with a background in contractual and collaborative research activities may share important know-how with their students, making a contribution to their further academic career. A vibrant start-up culture may be a key incentive for focusing on entrepreneurship in teaching curricula. Participation in joint activities may also improve universities' research reputation, signalling its high quality and reliability, which may lead to an increase in external financing and facilitate the procurement of academic talent. These are just a few examples, depending on the specific characteristics of individual universities' involvement in knowledge transfer and the incentives and potential of the surrounding ecosystem, this range may be much wider. Figure 2 gives an overview of human potential and the institutional environment on research productivity with account of externalities and spillover effects caused by active engagement in transfer activities by the performing institutions according to their status and potential.

When developing policy support measures for the KT, these interdependencies between transfer channels and the internal structures of universities have to be taken into account. The latter cannot be solely considered a positive effect from knowledge acquisition and rising potential, as it may cause conflicts in fulfilling teaching and research functions. In the context of the KT, businesses' links to research and transfer mechanisms must be viewed not only as unilateral and bilateral knowledge flows as part of certain projects but as a process of creating an innovative environment and forming agendas, which would unite all three corners of the KT. These activities typically include medium- to long-term collaboration between universities and partners from both the public and private sector. Examples include excellence center schemes (best practices are demonstrated in Sweden or Austria), which aim to transform basic research outcomes into applied knowledge and solutions for companies. Other instruments, such as cluster programs or development and innovation platforms, put a greater emphasis on applied research

Figure 2. **Analytical framework of external engagement by academic researchers**



Source: compiled by the authors using [*Perkmann et al.*, 2012].

and innovation. One can distinguish between them based on who initiates research projects with students and academics — either companies or the public sector.

Analysis of policy instruments and measures related to the Knowledge Triangle

To evaluate the efficacy of the KT activities is challenging because it is rarely addressed explicitly in institutional activity or national policy paradigms (with a few exceptions such as the strategic vision of Aalto University, see [*Markkula,* 2013]). Any assessment of policy instruments and measures is usually carried out on the basis of the implicit structure of applied mechanisms, targets and performance indicators. When evaluating research and innovation strategies, besides measurements of productivity, or the positive and negative effects of the adopted measures, one must consider the ties and interrelationships between these strategies.

During the evaluations of public programs, in particular those aimed at developing ties between research and business or those aimed to foster scientific excellence, the effectiveness and productivity of such programmes are analysed, whether specific program goals or policy targets have been met is considered. Evaluations have to be distinguished from monitoring of concurrent developments or performances. Despite the fact that in many countries' higher education systems a holistic view of HEIs' functions is already used, their total contribution to research, education and innovation is rarely measured. Monitoring systems, whether they apply numeric indicators or contracted milestones are typically focused on only one of the three KT axes, therefore, these systems suffer from difficulties in properly addressing spill-over effects and externalities between the three spheres.

Acknowledging the difficulties of evaluation and the monitoring of systemic ties, the KT concept should not be treated as an independent subject of evaluation, but as a guiding principle for i) measuring the productivity of institutions, policy measures and programs and ii) an assessment of the level of outreach in research, education and innovation policies and iii) to uncover whether there is an excessive focus on any of them regarding funding, regulation or rhetoric.

The most successful attempt to create such an evaluation system was made in Sweden, where, in line with a 2012 government initiative, measurements and incentives were developed and tested for assessing the involvement of local universities in the social context [*Wise et al.,* 2016].

Place-based Policies and the Knowledge Triangle

Despite the increased global integration of research institutions, which was encouraged by developments in digitalization and transnational research cooperation, geographical proximity continues to be an important determinant for the engagement of HEIs in knowledge transfer activities. Several studies (e.g., [OECD 2007; *Veugelers, del Rey,* 2014; *Goddard, Puuka,* 2008; *Unger et al.,* 2016]) on universities' contributions to regional development allowed for developing a broad classification of transfer channels, which play a critical role especially in the regional context. The functions, as well as the readiness of companies to establish businesses in this or that region, are determined by the features of the local ecosystem (business climate, investment opportunities, the presence of business communities), which in turn affects a region's economic performance and competitiveness.

The typical instruments for formalizing and organizing knowledge transfer activities are by their nature tied to their region of location and cooperation with geographically close actors, these instruments include, for example, clusters, science parks or incubators. A key factor in determining the attractiveness of a region is the presence of highly skilled specialists on the local labor market, and HEIs are responsible for educating these people. Companies quite often express their educational needs to HEIs by participating in the development of curricula or collaborative educational programs such as dedicated professorships or courses.

Furthermore, besides contributing to the competitiveness of a region within the global competitive space by bringing in companies, HEIs are decisive factors in shaping the social, demographic and cultural structures of a region. A region's ability to bring in young, educated workers positively impacts the development of its infrastructure, including schools, kindergartens, and the hosting of cultural activities.

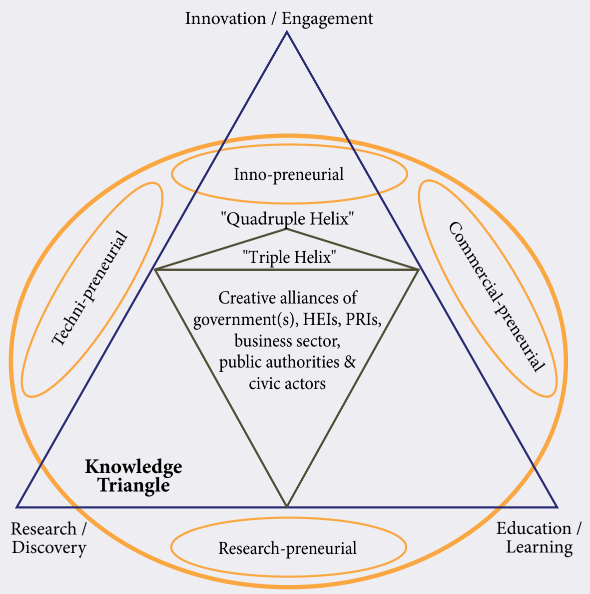
Additionally, HEIs provide direct economic stimuli for regions i) as an employer (of not only academic personnel), ii) by the demand created by its students, iii) by expenditures and investments in the construction of infrastructure [*Musil, Eder,* 2013], iv) by contributing to the "branding" of a region, some examples if this phenomenon include Oxford, Cambridge, Princeton or Harvard, which may enhance a region's reputation as well as its attractiveness as a tourist destination.

HEIs are also affected by not only knowledge transfer but also by the local environment. The institutional, geographical or ecological environment (including architecture, rivers, mountain ranges, fauna and flora) may become the starting points for the development of unique research and educational specializations and competencies at the local universities. An example is the research focus on the Alpine Region by the University of Innsbruck in Austria. In line with the changing principles of OECD regional policy, regional ecosystems are considered key factors in determining not only HEIs' activities but also the performance of the national innovation systems in general. Traditional cohesion policies, focusing on transfers to lagging regions, have increasingly been replaced over the past two decades by an integrated approach emphasizing innovations that arise from regional knowledge-based ecosystems. Universities and higher education institutions play a vital role in these new socioeconomic models, first, because they are the central providers of knowledge and skills, second because they can support policymakers in the development, implementation and evaluation of strategic concepts and policy measures.

The concept of *smart specialization* is directly tied to the coordination between regional actors in the KT. Smart specialization serves as a key paradigm for the formation of regional structures, combining several spheres of the KT as a driving factor in achieving sustainable, knowledge- and innovation-driven regional development [European Commission, 2012; OECD, 2014a,b,c,d]. Many countries, regions or sub-regional administrative entities, such as cities and municipalities, to some extent participate in STI policy matters. Therefore, in Germany and Spain regional administrations develop strategies supporting innovative infrastructure (clusters, etc.), participate in the formation of research, technological and innovative policy. Depending on the constitutional status of regions in this or that country, the mechanisms for coordinating STI policy may vary. In Denmark, for example, the Regional Growth Forum is a legal entity and coordinates the actions of local scientific, economic and political actors in a region. In the Netherlands, so-called "triple-helix" structures have had a long tradition in facilitating the coordination of regional actors, who are often organized as jointly financed councils or associations, which in turn organize multilateral projects in which residents from other regions participate. The Swedish VINNVÄXT program serves as an example of a holistic, integrated approach. This program gives impetus to bottom-up initiatives for the identification of priority areas for action, contributing to knowledge-based regional development.

Involving HEIs in the life of a region is no easy task for politicians. Challenges for implementing and assessing policies in this vein arise especially due to differences in their teaching and education missions and the heterogeneity of the institutional landscape of regions. The management systems and financial state of universities, innovation policy, and regional development depend on the distribution of responsibilities between the federal and regional levels. Such a complex array of factors can lead to contradictions in the use of stimulus mechanisms. Consequently, the degree to which regional structures and innovation policy planning as well as implementation can address the entire KT varies greatly. Therefore, during the development of KT policy at the federal level, in particular, regarding the funding of HEIs, one must consider the role and potential of regional ecosystems.

Figure 3. The Knowledge Triangle as an integrative policy framework



Source: compiled by the authors.

While these structural differences create difficulties in assessing and benchmarking the regional engagement of HEIs, other difficulties stem from contradictions between HEIs' regional engagement and their aspiration to become competitive on a global scale through their research and ability to bring in talent. In some countries, the task of developing university ties with the surrounding region is formally proscribed in performance agreements and contracts. Despite this, universities must search for a balance between a focus on the location-based dimension and the tasks of effective educational and research activity and the commercialization of developments. This aspect is poorly reflected in monitoring schemes and performance indicators.

The Knowledge Triangle as an integrative framework?

The KT concept was used throughout as a common analytical framework for the analysis of whole systems as well as for specific cases and institutions by the Working Group on Innovation and Technology Policy (TIP) under the OECD Committee for Scientific and Technological Policy (CSTP). The study stipulates the systemic cooperation between actors representing the spheres of education, (academic) research, knowledge creation and innovation. Many of the interactions dealt within the KT framework also feature prominently (though from different angles and perspectives) in analytical frameworks such as the "triple helix", "entrepreneurial university" and other such schemes. So, in Sweden and Canada, many researchers and research departments at higher education institutions are not (yet) familiar with the KT concept, though they certainly engage in KT activities (knowledge transfer, cooperation with companies, education, etc.). Nevertheless, some universities explicitly address the "third mission", "entrepreneurial university" or "triple/quadruple helix" as part of their mission and in their strategy documents.

Although common patterns exist that determine the role, behaviour, and organizational characteristics of universities, when deriving a general policy, one must be careful given the great deal of institutional diversity and compare institutional facilities and challenges.

Figure 3 shows how the KT could serve as integrative framework for the variety of concepts discussed in this paper that all refer to (though to varying degrees) a broader understanding of HEI's role in social and economic development. The KT serves as a guiding principle for the development of policies by anticipating the formation of ties between research, education and innovation.

Irrespective of which concept is adopted (KT, "triple/quadruple helix", "civic or entrepreneurial university"), they all demand a policy or strategy that is aware of the interrelatedness of the activities, potential trade-offs, and the necessary differentiation between incentives and instruments in addressing different approaches and actors. Many HEI policy instruments still do not use an integrated approach to research, education and innovation. They still focus on single issues, such as education, commercialization, research ties between the academic and business sectors, etc. Strategies for developing ties between the research and business sectors still underestimate the benefits derived by both parties from such interactions.

The logic of the KT puts an emphasis on the ties between education, research and innovation activity. In accordance with the concept, each policy that solely addresses one of these spheres automatically has an effect on the other corners of the KT. However, the term “KT policy” only includes those policies, measures and instruments that explicitly address the integration of all three corners of the triangle. Examples of this include Finland's open innovation platforms or centers of excellence/competence Centers (e.g., Austria's COMET, Sweden's VINNVÄXT Excellence Centers and others).

The KT concept addresses several levels of policymaking, from local and municipal to regional and national as well as international authorities. The question of which vision prevails in the strategic interpretation of the KT therefore is dependent upon the focus of a national/regional innovation system and the country's STI governance system.

What could be derived from the several examples that were brought forth in this article is that the implementation of institutional transformations at higher education institutions and other organizations requires appropriate incentive mechanisms. These can include competitive public programs, national or regional strategies with dedicated budgets, specific measures for the allocation of public block grants, etc. Even small amounts of funds could have significant mobilization effects, especially when private funds are leveraged. The concept of the KT hence supports policymakers by providing a deeper understanding of the fact that investments in one corner of the KT tend to positively affect not only the other two corners but also create external effects, from enhancing the labor market and fostering structural economic change to improving society's standard of living. Thus, the KT should be first and foremost a practical policy framework, rather than simply a theoretical concept. Therefore, its success can and should be measured by its perceived usefulness for policymakers.

This paper was compiled as part of a project of the OECD CSTP/TIP Project 2015/16 on the Knowledge Triangle. It was prepared by Maximilian Unger and Wolfgang Polt of JOANNEUM RESEARCH – POLICIES to provide a conceptual discussion that lays out definitions of the concept of the Knowledge Triangle and how it relates to the national innovation systems framework and related concepts.

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Higher Education Institutions in the Knowledge Triangle

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Abstract

This paper discusses some of the policy issues and best practices aimed at enhancing HEIs performance and improving their impact on society and the economy within the knowledge triangle. The knowledge triangle concept aims at exploring ways to better align and integrate the research, education and innovation functions of HEIs. The paper describes the contents of the knowledge triangle, HEI performance through the lens of this concept, policies to promote the knowledge triangle in HEIs, as well as potential contradictions in relation to other knowledge producers, such as public research centers and companies.

The conclusion is that there is no single model for universities and the knowledge triangle. This is due to the country-specific peculiarities of educational systems, diversity within HEIs themselves and the functions they perform, as well as the specific features of regional ecosystems. Accordingly, the key to the efficiency of the knowledge triangle tools is their place-based adjustment. In order to achieve a tangible contribution of universities to the development of regional and local innovation, it is necessary to ensure complementarities and a balance between their missions.

Keywords: knowledge triangle; research; education; innovation; third mission; regional ecosystems; place-based policy; higher education institutions (HEIs); universities; knowledge transfer.

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Higher education and public research systems are undergoing a system-wide transformation in OECD countries [OECD, 2016]. Decades of policy reforms in tertiary education, public research and innovation policy intersect, and sometimes clash, in the context of higher education institutions.

On the *research* side, global competition for scientific excellence and decades of disengagement from basic research on the part of companies has made HEIs the locus of national public research efforts. The mergers and restructuring of public research organisations (PROs) — many of which are focused on "mission-oriented" research — has also benefited HEIs, which have absorbed some PRO institutes. Denmark for example decided to integrate several government research institutions into its universities. In the UK as well, some institutes have also been absorbed by universities [OECD, 2011; *Ponchek,* 2016; *Vargiu,* 2014]. Project-based research funding schemes have also increased in recent years as a way for governments to try to steer research priorities at HEIs and improve accountability. Specialised centres of competencies/excellence have also been financed and positioned at HEIs in order to capitalise on existing strengths or to explore new areas and increase institutional differentiation.

On the *education* side, the conversion or upgrading of technical colleges into universities or universities of applied sciences has also expanded the higher education landscape and forced institutions to better differentiate themselves and their education market offerings. Meanwhile, firm-based activities and structures have evolved considerably in recent years (e.g., the rise of open innovation and global value chains, big data and dis-intermediation), creating new demands on HEIs in terms of talent and skilled graduates, but also in terms of the industry-relevant research to improve firm competitiveness [*Gackstatter et al.,* 2014; *Gokhberg et al.,* 2016; *Meissner et al.,* 2016].

On the *innovation* side, innovation policy has become a networked and decentralised government policy where innovation agencies or regional development bodies take on a greater role. Collaboration with public research, whether in the form of the science–push transfer of public research results to industry or demand-pull initiatives such as through public-private partnerships, has become the dominant discourse and a key focus of innovation policies. Even fiscal policies to support business increasingly target R&D collaboration between public research and large and small firms. Furthermore, the delegation of competences and innovation policies to agencies and regions has naturally brought innovation policies closer to the world of higher education policies, which has long had a strong regional or place-based dimension.

Entrepreneurship policies have also entered the fray as HEIs are being encouraged not only to educate and train entrepreneurs, but also to sponsor entrepreneurial activities on campus. In Norway, for example, all HEIs have entrepreneurship education, either as a special study programme or as a course embedded in other programmes [*Borlaug et al.,* 2016]. This is a rational development as Schumpeterian entrepreneurship is the main channel through which knowledge developed at HEIs finds its way into innovation [*Carayannis et al.,* 2015; *Proskuryakova et al.,* 2015]. This can be considered a consequence of the concept of the "entrepreneurial university" put forward in the early 2000s when Etzkowitz and Leydesdorff [*Etzkowitz, Leydesdorff,* 2000] described the Triple Helix and concluded that the university model is changing towards an entrepreneurial model, which stresses the application and exploitation of research.

However, if much of the support for basic research and tertiary education that is performed by HEIs comes from public coffers, government support to business R&D has also increased in the period following the financial crisis such that the amount of public investment that in some way or another is channelled through HEIs represents several percentage points of GDP: in 2011, 1.6% of GDP on average was dedicated to tertiary education institutions in the OECD in 2011 and 0.44% of GDP was spent on higher education R&D (HERD). Public support for business innovation that involves HEIs takes various forms such as:

- tax credits for companies collaborating with universities
- Small Business Innovation (SBIR)-type of schemes
- industry PhD programmes and student internships at companies
- innovation vouchers to help small firms wishing to purchase university research or consulting services, often funded by regional authorities.

The amount or proportion of this stream of public support to innovation is unmeasured, but anecdotal evidence suggests that it is important to certain HEIs and to certain regions/countries.

For these reasons alone, it is important to understand the following questions. How do HEIs position themselves within the KT and what are the implications for national innovation policies? To what extent do funding and governance policies support KT activities? Are "silo" funding streams for research, education and innovation a barrier for KT activities and what can be done to overcome this? How should one design policies for HEIs in countries with different industrial and higher education structures? Are there ways to link HEIs effectively with regional enterprise and social actors? And finally, what are the new institutional models and good practices to overcome these obstacles? These are some of the questions that the article aims to answer.

Importance of HEIs for innovation, education and research

HEIs matter for innovation for several reasons. First, HEIs play a mediating role between capital and labour in economic growth. HEIs train and develop productive human capital through teaching activities. Human capital accumulation has been an important driving force behind aggregate economic growth [OECD, 2008]. Compulsory education remains the first channel for human capital accumulation, especially in developing and emerging economies. In advanced countries, however, which are closer to the technological frontier, investment in tertiary education provides high social returns from the accumulation of knowledge capital and spillovers in the economy, which justify the fact that governments directly or indirectly subsidise 70% of tertiary education in OECD countries. Over the past decades, OECD countries have supported the increasing participation of students in tertiary education, mainly at universities. Of course, there are also high lifetime private returns from tertiary education which increases demand for HEIs. There are also distributional effects on equity and income inequality that arise from access or lack thereof to higher education. These effects, however, are outside the scope of this paper, which focuses on the contribution of HEIs to innovation systems.

The second reason HEIs matter is that they carry out a large share of public research, both basic and applied. A properly organised higher education system can increase the efficiency of research activities, which in turn increases the stock of knowledge capital — as distinct from human capital — which is the basis for technological progress. In endogenous growth theories, knowledge capital is suggested to have a greater potential for constant, rather than diminishing, returns, thus providing a mechanism for permanent growth effects from increases in capital. In these models, HEIs are part of the knowledge-producing sector, the other part being R&D-intensive firms. In many OECD countries, half of the national efforts concerning research are carried out by HEIs and public research organisations (HEIs). However, one fundamental difference between the knowledge capital created in HEIs and the knowledge capital created in firms are the incentives. Firms have the incentive to invest in research when the outcomes of the R&D can generate market power (through intellectual property rights, IPRs) and higher profits.

The third reason that HEIs matter is that they contribute to local economic development through so-called "third mission" activities or "community engagement". The third mission is a broad concept that groups together the concepts of the entrepreneurial and commercial activities of HEIs, their social and cultural relevance, and knowledge transfer. The term is generally used in science and innovation policy to capture knowledge exchange activities; in the education community, the term is used more frequently to refer to the role that HEIs play within their community. This concept is not new; both knowledge exchange and community engagement are long-standing characteristics of HEIs in most OECD countries. However, during the dual move towards increased autonomy and accountability for HEIs in most countries, many countries have acted to strengthen and formalise the social and knowledge transfer role of HEIs. Third-mission activities include, but are not limited to:

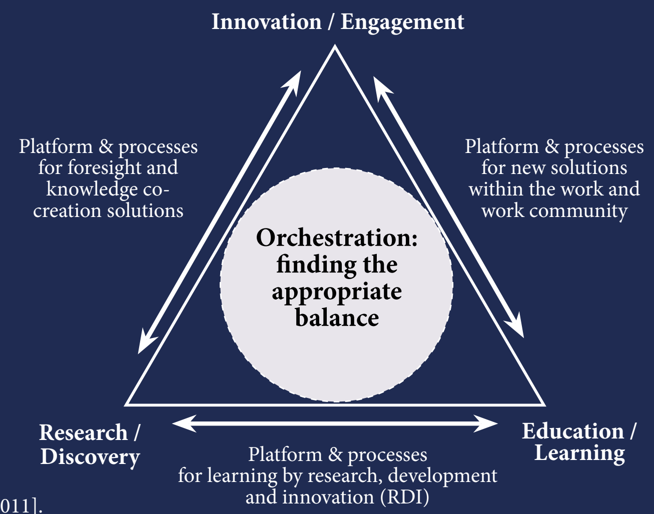
- informal engagement with industry;
- consulting and advisory activities of academics;
- inputs for public policymaking;
- support for entrepreneurship skills among students and researchers;
- exploitation of the results of research activity;
- the creation of links between universities and vocational colleges;
- contribution to community interaction (e.g., classes for non-students).

Goddard and Puukka [*Goddard, Puukka,* 2015] note that many third-mission activities are often confined to the periphery of management and leadership of the higher education system. The notion of a third mission varies across countries, but in many cases, it is an unfunded mandate and expectation placed on HEIs and, to a lesser extent, on PROs. While the traditional core focus of leadership of research universities is on research excellence, teaching (and the appearance of both in published rankings), and third-mission targets mandated by central and regional governments, many other activities do not have the same incentives. The drivers and incentives for teaching, research and external engagement are often unrelated and competing.

The fourth reason that HEIs matter has to do with their contribution to local economic development. Knowledge is created locally and while some of this knowledge can be codified and diffused globally, much of the tacit knowledge generated by students, faculty and firms is "sticky" and remains so that the spillovers are localised. Furthermore, highly skilled graduates contribute to the quality of the local workforce. HEIs are themselves large employers and provide services to companies and public agencies (e.g., university hospitals) in the regions. They are also factors of "attractiveness" for national and local economic development strategies, drawing in faculty, students and also companies from outside regions or countries to co-locate around universities in order to obtain access to the talent and cutting-edge research.

Finally, and as a result of the above functions, HEIs have become central actors in innovation systems. The national innovation systems theory considers HEIs key actors in the performance of national innovation systems given their important functions. However, HEIs are also under tremendous pressure from governments and other stakeholders to transform themselves in order to cope with the realities

Figure 1. **Knowledge Triangle**



Source: [*Sjoer et al.*, 2011].

of the globalisation of higher education and research, the expansion of tertiary education and the increasing demands for equity and access. HEIs also continue to face budgetary pressures in light of the decentralisation of higher education funding in many countries as well as the competition for research funding. The transition to the digital age in education (e.g., Massive Open Online Courses — MOOCs) is another challenge, but also an opportunity for HEIs. Indeed, research and education ministries in many OECD countries are looking towards the "knowledge triangle" as a framework to help HEIs improve their impact on society and the economy.

What is the Knowledge Triangle?

Traditionally, the linking of research to innovation has been encouraged by governments and industry. In addition, in HEIs with a Humboldtian tradition (e.g. in Germany, the US and Northern Europe) the linking of research with education has been well established since the 19th century. However, this link has continued to evolve as governments channel greater amounts of research funding toward HEIs. In contrast, the links between education and innovation have been less the focus of national policymakers or institutional leaders until recently.

The knowledge triangle is a policy framework that stresses the need for an integrated approach to research, innovation and education policy with a focus on HEIs as knowledge creating institutions. It was conceived in 2000 as part of the European Union's Lisbon Strategy in response to a lack of innovation and entrepreneurial culture in research and higher education; a lack of investment, in particular private investment, in research and development (R&D); and the difficulty European countries face in translating R&D results into commercial opportunities.

The knowledge triangle postulates that knowledge generated by HEIs is the result of three core elements (the vertices) which are: i) education; ii) research and iii) innovation. Each of these elements influences the others. These bi-directional or circularly-caused knowledge flows between the three core elements of the knowledge building process constitute the Knowledge Triangle (Figure 1).

At the centre of the triangle, orchestration tools, understood as the tools to mobilize and integrate resources to create value for the members of the knowledge network [*Wallis,* 2006], are set-up in order to provide an overall articulation and achieve balance between the different components of the knowledge creation system [*Sjoer et al.,* 2011]. In practical terms, they typically correspond to multi-stakeholder platforms (virtual, in-person and/or mixed), bringing together actors from the public, private and academic sectors around joint research and educational collaboration. The model stresses the equal importance of each of the elements of the knowledge creation process (an equilateral triangle) as well as on the need for an integrated, holistic approach that focuses not only on each of the single vertices, but especially on the two- and three-way interactions between education, research and innovation [*Markkula,* 2013]. In such interactions, there are positive externalities that spill over to each dimension [*Hervás Soriano, Mulatero,* 2010]. Each of the linkages in the triangle can be strengthened by means of platforms and processes that build bridges between education, research and innovation, thus facilitating the circulation of knowledge [*Sjoer et al.,* 2011].

The novelty of the knowledge triangle concept, however, is that it draws attention to the contribution of education to research and that of education to innovation. Traditionally, policy has been concerned with the contribution of education to labour market success or the training of highly qualified graduates for research activities. With regard to the innovation function, most policies have focused on increasing the contributions of research to innovation through legislative reforms (e.g., the Bayh Dole Act) and the establishment of technology transfer offices (TTO) or other interfaces between research and innovation at firms.

The link between education and research

In terms of the linkages between education and research, the importance of skilled human capital for successful R&D activities has long been internalised by science and research policies. Currently, many countries have science development policies based on a combination of postgraduate training, scientific (fundamental/basic and applied) research funding and advanced human capital insertion programmes. The current financial pressure on HEIs has, however, increased concerns and interest in the cost-benefits of such instruments.

The relationship between R&D and innovation

The other most policy-dominant side of the KT is the relationship between R&D and innovation. The poor performance of innovation systems in turning R&D efforts into innovations has motivated the implementation of a wide range of policy instruments for increasing the transfer of knowledge from universities to the productive sector. Some initiatives include: i) legislative reforms (the Bayh Dole Act), ii) public-private partnerships; iii) university-industry research contracts; iv) intellectual property rights (IPR); v) university spin-offs; vi) knowledge transfer offices; vii) business incubators viii) labour and student mobility; ix) consultancy activities; x) conferences and xi) electronic collaboration platforms.

Geuna and Muscio [*Geuna, Muscio,* 2009] provide a comprehensive critical analysis of the current approaches to and mechanisms for the institutionalisation of knowledge transfers from academia to the productive sector in Europe and the US. After 30 years of experimentation in knowledge transfer policies, the authors conclude that there are more failures than successes, largely due to the incapacity of knowledge transfer policies to manage the trade-offs between the university's more traditional roles of teaching and knowledge generation with the increasing pressures for greater knowledge transfer. Some problems identified by the authors include the partially tacit nature of knowledge (not easy to transfer), the costs of network building and the difficulty of pricing knowledge. As pointed out by Hervás Soriano and Mulatero [*Hervás Soriano, Mulatero,* 2010], despite the fact that innovation can increase the efficiency and scope of R&D activities, innovation policies still suffer from a unidirectional approach going from research to innovation, rather than from innovation to research or education and then back into innovation.

The link between innovation and education

Finally, in terms of the link between innovation and education, the KT perspective is interesting. Two aspects emerge as critical. In first place, the push to develop an entrepreneurial attitude among students has motivated a range of entrepreneurship education programmes [*Oosterbeek et al.,* 2010]. Second, there has been an effort to adapt educational programmes to meet the needs of the productive sector or at least to involve industry on university boards. Although there are successful examples of universities that have succeeded in engaging with industry, the complex governance of the HEIs and entire higher education systems is a barrier in many cases [*Maasen, Stansaker,* 2011]. Yet, it is possible to find some cases that service as interesting examples of HEIs that have internalised the KT principles in their educational and business models. Some examples include the Aalto University [*Markkula,* 2013; *Pirttivara,* 2013] or the Catholic University of Leuven (KU Leuven) in Belgium [*Van Petegen,* 2013]. The particular initiatives undertaken by universities and public authorities are varied, including:

- The Living Labs model in Laurea University of Applied Sciences (Finland) [*Hirvikoski,* 2013]
- Tailor-made Continuing Engineering Education (CEE) programmes at Delft University (the Netherlands) and Aalborg University (Denmark) [*Sjoer et al.,* 2013]
- Life-long learning programmes at KU Leuven (Belgium) [*Van Petegen,* 2013]
- The Aalto Camp for Societal Innovation (ACSI) of Aalto University (Finland) [*Pirttivaara,* 2013]
- Ecosystem networks in the Netherlands such as Brainport and Twente, which promote the knowledge triangle from a place-based perspective [*Stam et al.,* 2016].

Again, we know very little about the reverse relationship, from innovation to education. In this regard, KT policies have been limited to the promotion of some innovations (mainly ICT's) for educational purposes [*Hervás Soriano, Mulatero,* 2010]. The knowledge triangle concept calls for an articulated approach based on both strengthening education, research and innovation, but above and beyond that, on reinforcing the interactions and positive externalities that are established between them. Thus, it implies a departure from the traditional view of knowledge production as a linear and sequential process and instead calls for a more systemic approach to research, education and innovation policies.

While its comprehensive focus makes the KT an appealing framework for policies aimed linking knowledge creation to innovation, it provides limited insights on the specific ways such interactions unfold and on how they should be governed. This is because of the diversity of countries' economic structures and the roles HEIs play in various countries. This suggests there is no single model to which countries should aspire.

HEI performance in the context of the knowledge triangle

Higher education systems vary widely across countries. The position and structure of HEIs is closely linked to long-term cultural and historical factors in different countries [*Hartl et al.,* 2014]. While HEIs broadly perform the same role across different countries, their perceived cultural and historical significance varies. In some countries, HEIs have historically been very close to the state; in others, they have tended to be more independent and subject to competition. This context is likely to affect the characteristics and activities of HEIs across countries, as well as the collaboration activities they form. For instance, research is embedded into the mission of the HEIs in some countries, whereas in others it is a more recent activity of the sector. Higher education systems also vary in the degree of government intervention. Even in market-based education systems, the state normally intervenes and regulates to ensure quality and to set standards. In addition, through its role as a key funder of research in most countries, the state maintains some influence over research practices, as well as being a major source of incentives for HEIs. However, the levels of government oversight vary significantly across countries and, as a result, institutions have different levels of accountability and freedom to decide their own practices. Autonomy in higher education can take many forms. Decision-making and revenue-raising autonomy differ from academic autonomy, meaning different actors within HEIs may experience different forms of independence.

HEI diversity

HEIs encompass a range of different types of institutions. A broad definition of HEIs includes not only universities but colleges, academies, institutes of applied sciences, professional institutes, trade schools, and other organisations awarding academic degrees or professional certifications [IPP, 2015a]. The balance between the different types and sizes of HEIs varies significantly between countries. Universities of applied sciences are a common feature of some higher education systems in Europe, but other countries only distinguish between university and other non-university institutions. Similar diversity can be seen when looking at countries in Asia [*Altbach, Umaskoshi,* 2004] and North America [*Davies, Hammack,* 2005]. In terms of their activities, diversity in the population of HEIs can be characterised as horizontal or vertical. Concerning education, horizontal diversity implies that different courses and institutions serve different objectives and different streams of students [OECD, 2008]. However, horizontal diversity also applies to research and knowledge exchange activities, for instance, based on the intended audience for research outputs [*Daraio et al.,* 2011]. Vertical diversity implies some degree of hierarchy of institutions (e.g., between "elite" research universities and vocational colleges), either in terms of reputation, or often in terms of the rewards built into government policies on accreditation, autonomy and funding allocation. The degree of vertical HEI diversity depends greatly on national policies and practices.

Research activities and research quality are major elements of diversity and differentiation between HEIs. While almost all HEIs teach students, the extent of research activities varies considerably. There are more readily available measures for vertical differentiation in research activity. By contrast, measuring and comparing teaching quality and human capital at the higher education level can be problematic. Another common component of diversity among HEIs concerns their activities outside of education and research. Such activities are often referred to as the "third mission" of HEIs and include, but are not limited to: informal engagement with industry, consulting and advisory activities by academics, contribution to public policy, support for entrepreneurship skills among students and researchers, the exploitation of research activity, links between universities and vocational colleges, and the contribution to community engagement (e.g., classes for non-students). The intensity of these types of activity among HEIs also varies according to historical factors and national policies.

The concept of the mission of HEIs is not universally agreed-upon. As an alternative, Laredo [*Laredo,* 2007] proposes an alternative three "functions" of universities, all of which involve different ways of interacting with society: mass tertiary education; the professional training of specialists and research activities with close ties to non-academic actors; and conduct of fundamental research and the training of research personnel.

Diversity within HEIs

Another important dimension of diversity concerns differences within HEIs. In particular, different fields of study are associated with very different types of education, research and other activities. Faculties within the same institution often have their own budgets and sources of funding and, as a result, may form a variety of different types of external relationships. These differences can have institution-wide implications, depending on the degree of subject specialisation of the HEIs. In addition, academic freedom often means that researchers and staff within the same institution undertake a wide range of practices and hold a wide range of sometimes contradictory values. Diversity within HEIs raises a number of questions and challenges for the tools and strategies concerned with the knowledge triangle.

Funding

One manifestation of this diversity is that the patterns of public and private expenditure on higher education vary greatly across countries. In many systems, HEIs are highly dependent on public financing. In others, private expenditure (including from tuition fees and non-public funding of R&D) is a more prominent feature of higher education. In three of four OECD countries, which spend the highest proportion of national wealth on HEIs, private sources account for at least 65% of the total investment, whereas private sources account for only around 5% for the fifth and sixth biggest spenders on higher education. There is also a regional element to expenditure patterns; in general, the proportion of private expenditure is higher in non-European countries. The share of private expenditure on tertiary institutions increased between 2000 and 2011 across OECD countries, and a number of countries substantially increased tuition fees for students during this period [OECD, 2008]. The general decline of public research funds has led to an increasing reliance on alternative sources of funding by universities (including the revenues from an increasing the number of students, consultancy activities, funding from non-profit organizations, etc.) [*Geuna, Muscio,* 2009].

A second important implication is a more targeted allocation of research funds to top-research universities [*Massen, Stensaker,* 2011]. A consequence of both concurrent trends would be the growing segmentation of the HEI market between teaching and research universities. While some authors have argued that such segmentation is actually efficient from a resource allocation point of view (e.g., [*Aghion et al.,* 2009]), others claim that it may bring problems to the whole university system. Massen and Stensaker [*Massen, Stensaker,* 2011] for instance, argue that the university's market segmentation may lead to an undesired break between education and research, which undermines academic standards, particularly at the undergraduate level. According to the authors, the focus on knowledge transfer in current EU policy may accelerate the process.

A far less understood relationship is the reverse link, from research to education. Hervás Soriano and Fulvio Mulatero [*Hervás Soriano, Mulatero,* 2010] argue that a rapid update of university curricula to ensure they include recent results from research should be a natural process at universities, but in practice, it is curtailed by the "hysteresis" of higher education institutions. In any case, it is hard to find specific examples of policies aimed at increasing the feed-back from research to education from which one might draw some lessons.

HEIs' role in national innovation systems varies across countries

Given the diversity of HEIs at the system and institutional level, the roles of universities within national innovation systems depend on a range of factors. HEIs do not operate in isolation in science and innovation systems. Rather, they act alongside government research, public research organisations (PROs), various forms of innovation bridging institutions (technology transfer centres, incubators, etc.), and national intellectual property protection laws, the structure of which all vary across countries. In addition, a diverse set of knowledge sharing agreements, institutions, social relationships, networks and infrastructures grouped under the term knowledge networks and markets (KNMs) provide a number of critical services to firms, organisations and individuals to engage in the meaningful exchange of knowledge and associated rights [OECD, 2011].

The successful contribution of HEIs to innovation also requires a demand for the knowledge they produce, both from firms and the government sector. Indeed, many countries have policies to encourage firms to collaborate with universities or PRIs and use their research services [IPP, 2015b]. However, the nature of this demand depends on factors such as industry structure and specialisation — evidence suggests that most firms typically look for new solutions within their existing areas of expertise [*Fagerberg, Godinho,* 2005]. Variations in industry structure may, therefore, also have an influence on the role that HEIs play in national innovation systems. As a result, the place that HEIs occupy within national innovation systems can be argued to be inherently tied to long-term, structural economic factors in a path-dependent process [*Mowery, Sampat,* 2005]. Indeed, a recent OECD presentation [OECD, 2015] showed how some innovation systems are more HEI-dominated than others. Therefore, from an innovation system perspective, there is no single success model for HEIs or for the knowledge triangle. The "optimal" structure of institutions that support innovation is likely to vary across countries. Different types of institutions can equally contribute to innovation via their education, research and other activities, in conjunction with other actors, institutions and networks. For example, applied technological and clinical research often has the clearest links with industrial innovation, especially the measurable indicators of patents. Curi et al. [*Curi et al.,* 2013] show that the efficiency of technology transfer offices positively depends on the size of the institution, the degree of science and engineering specialisation, and the amount of privately-funded R&D activities. That said, HEIs specialising in fundamental science help provide the knowledge for applied sciences to operate at the knowledge frontier. Furthermore, small teaching-only institutions may play an important role in developing the technical, creative and managerial skills that contribute to innovation. Moreover, HEIs are part of international networks, meaning country systems may specialise in particular fields.

Well-functioning education, research and innovation systems may therefore rely on the contributions of different types of HEIs. Diversity and differentiation imply that HEIs cater to different audiences in their education, research and innovation activities. They are therefore subject to different expectations. The "reach" of an institution's activities is, therefore, another measure of diversity. Large leading research universities are connected to global scientific networks, whereas small colleges are often focused on the needs of their local communities.

Diversity and the concentration on HEI performance

Understanding the diverse contributions of universities to innovation is critical in the design of research policy [*Bonaccorsi et al.,* 2014]. Statistics show that, in a sample of the US and a number European countries, a small number of large institutions are responsible for a significant share of higher education student enrollment. The concentration of research and innovation activities appears even more concentrated, however the concentration of activity is not homogenous across systems. National university systems include a large variety of institutions, with a few large institutions and a much larger number of small universities.

What are the advantages and disadvantages of concentration? This is a critical issue from a policy standpoint as government research support programmes often directly influence the extent of concentration. The fact that more money might go to the HEIs that are deemed the best according to certain criteria would mean that they would grow in line with their quality, generating a concentration of resources at the best performers. The initial descriptive evidence suggests that, on average, HEIs with a larger student enrollment do not receive clear advantages. In the United States, institutions that have larger student enrollment have higher graduation rates, on average, and those that conduct more research and engage more in innovation have higher graduation rates than those that do not. Howevwer, the best institutions are also attracting students with the highest test scores, and once taken into account, the correlation between enrollment and graduation rates is weakened. Possible advantages of the concentration of activities within a few universities would arise if there are gains in size. These may be economies of scale in university outcomes, i.e., if larger institutions can produce better outcomes relative to their resources compared to smaller institutions [*Cohn et al.,* 1989]. Another possible advantage from concentrating resources in only some institutions is the economies of scope that arise if the production of one output improves that of another output or its quality. For instance, engaging intensively in research might support innovation or education outcomes [*Chavas et al.,* 2012].

However, at a certain point, there could also be diseconomies of scale in education arising from factors such as overcrowding or low levels of personalised learning [*Robertson, Bond,* 2005]. Diseconomies of scale could also affect research and innovation activities. Moreover, engaging in one activity may negatively affect engagement in another activity as for instance, innovation activities that may negatively impact the quality of research.

Policies to promote the knowledge triangle in HEIs

Governance, autonomy and competitive funding

The central issue in the governance of the knowledge triangle is to understand where the responsibility for the knowledge triangle framework lies, which governmental and institutional actions and policies must be put into place so that the HEIs can link the different functions of institutions. A second issue is to determine what barriers are in place, impeding good governance between government and institutions as well as within institutions. Further, which governance arrangements are more conducive to high-quality KT interactions and overall impacts? What interesting lessons in terms of success or failure have emerged from the experience of institutions that have undertaken or adopted the KT approach?

National higher education policies have changed considerably over the past few years. In line with changes to cross-government public management processes towards a market orientation and efficiency, there have been a number of prominent efforts to modernise higher education for the knowledge-based society. One of the most significant trends has been a move towards greater autonomy for HEIs [*Estermann et al.,* 2011], and more focus on competition between institutions for funds, students, staff and reputation. Institutional autonomy is an important ingredient for high performing universities. One issue that has been explored in the literature is the link between autonomy and third mission activities. Aghion and Howitt [*Aghion, Howitt,* 2007] find that the more autonomous institutions in the US and Europe are, the more successful they are in establishing formal and informal ties to industry and other organisations. Furthermore, autonomy appears to increase research universities' productivity and one sees that research universities are more useful in places closer to the frontier of science and discovery. However, the difference in productivity between autonomous and non-autonomous research universities is just as significant away from that frontier as it is close to it. The aforementioned authors postulate that this may be because autonomy allows a university to direct resources toward more productive research and researchers. Results for the US also convincingly demonstrate that more financial investments are translated into degrees at a higher rate at more autonomous universities.

Autonomy and competition can influence the incentives faced by HEIs in both positive and negative ways. Using data from international university rankings, Aghion et al. [*Aghion et al.,* 2008] find that budget autonomy has a large impact on the research performance of universities, controlling for other factors, but other indicators of autonomy have no statistically significant effect. Increasing the competition for students (though a long-running feature of some systems) may increase incentives to improve student outcomes and employability. This could result in teaching practices and other training that are closely aligned to those valued by students or employers. However, competition can also take on more perverse forms, such as offering a wide range of ancillary services, grade inflation or attracting international fee-paying students [*Abbott, Doucouliagos,* 2009], which have less clear benefits for education, research and innovation. Furthermore, competition is skewed by the nature of higher education as a "positional good" [*Marginson,* 2006].

Therefore, ensuring competition leads to socially beneficial changes is a challenge for the new accountability and governance mechanisms. The high degree of autonomy and strong traditions, especially within specific academic departments, can also be a barrier to greater engagement with industry and the broader community. One key finding is that autonomy also requires the creation of leadership and strong incentives (including financing) in transforming university missions and performance [*Goddard, Puukka,* 2008].

In case of institutional core funding, HEIs usually have a large degree of autonomy in deciding whom and what to fund. In contrast, research funds that are provided on a contractual basis by the government and industry often come with conditions that define the boundary of use. The extent to which governments place conditions on public funds is one of the most important issues for both policymakers and HEIs, as they may affect the governance of institutions and the behaviour of individuals at those institutions, as will be discussed later in this paper.

Multilevel governance

Increased autonomy from government has often been accompanied by increased formal accountability mechanisms. The influence of government policy on higher education has become increasingly indirect in nature. This trend has manifested itself in a variety of new multilevel governance systems for HEIs. There has been a general shift away from negotiated budgets for HEIs towards explicit performance agreements [*Salmi,* 2007]. In many countries, priority-based funding formulas for teaching have been introduced, which focus on labour force needs or performance measures such as graduation rates. Almost without exception, increased autonomy has been accompanied by more robust quality assurance mechanisms, which are overseen by a national agency [OECD, 2008]. The processes involve a mix of accreditation, assessment (or evaluation) and audit [IPP, 2015a].

Competitive funding

Competition for research funding, for example, has increased. There is evidence across the OECD of a relative shift away from core research (block) funding for institutions towards competitive project-based funding [OECD, 2008; *Poti, Reale,* 2007]. However, block funding has become more common than itemised funding as a means of government financing of HEIs' teaching and administration tasks [OECD, 2008], although often by means of a formula based on quasi-competitive variables such as the number of students. These changes have been intensified by the massification of higher education and by global competition for researchers and students. More competitive funding systems are likely to affect the incentives of researchers. In the face of a more competitive environment, the purpose of HEIs has come into question. Many countries have witnessed the rise of HEIs as competitive, more business-like institutions with less easily defined missions [*Marginson, Considine,* 2000]. They have become hybrid institutions with both a public mission and a private one. These trends have given rise to terms such as "entrepreneurial universities" and "academic capitalism" [*Bramwell, Wolfe,* 2008]. Internal governance and institutional management has also changed. HEI leadership has moved towards an increasingly top-down model, where department heads and university presidents have greater management and coalition-building responsibilities, and they have been given direct power over nominations and strategic focuses in education and research. The implicit contradictions between the private missions and public ones can have a bearing on research and education. Using data from university collective bargaining agreements in the United States, Rhoades [*Rhoades,* 1998] found that academics' autonomy with respect to activities such as designing curricula or introducing new instructional innovations was declining as university management became increasingly centralised.

Competition for students, funding and reputation may have pushed HEIs to broaden their activities beyond their traditional remit. There is evidence in some countries that university and non-university distinctions are blurring, with the latter group starting to conduct more academic research [*Lepori,* 2008]. This process is sometimes known as "academic drift". In the context of the massification of higher education and higher competition, and given sufficient flexibility, revenue-seeking universities also have an incentive to expand their role, for instance, by bringing in students that may otherwise have received vocational education. In this sense, HEIs have diversified their educational offerings in the face of competition. Indeed, whole new institutional models have arisen in response to the changing higher education environment [OECD, 2008]. Competition for students and researchers at the global level may encourage HEIs to become active players in international networks and seek ways to enhance their international reputation.

Industry funding of HEIs

In the face of budgetary constraints faced by most countries, HEIs have changed their attitudes towards business as an additional source of funding, encouraged by reforms and government policies. Industry funding for HEIs varies across OECD countries. Data shows that industry is a more important funder of higher education R&D (HERD) in some countries than others. In France and Japan, industry accounted for 2.7% of HERD in 2012, compared to 14% in Germany. Across OECD countries, the percentage of HERD financed by industry rose dramatically during the 1980s, but has been more stable since, declining after the start of the 2008 global financial crisis. One must note, however, that industry is not the only private source of funding for the activities of HEIs; non-profit foundations, philanthropic organisations and citizen initiatives (community funding, crowdfunding) are also sources of non-state funding for research and education. The drivers behind these trends are a topic of interest for the positioning of HEIs in the knowledge triangle.

The relationship between HEIs and industry is more crucial in some fields than they are in others. In the US, medical sciences and engineering departments receive much more funding from the business sector than other scientific fields. An empirical study of Italian universities found that departmental differences had an effect on the extent of engagement with industry. The study also found that private funding is more of a complement to public funding than a substitute [*Mucio et al.,* 2013]. Furthermore, as industry funding is usually provided through contractual arrangements with explicit objectives and demands on research, the increasing role of industry in funding might have negative effects on the autonomy of research, and result in an increase in applied research relative to basic research. At the same time, the negative, neutral or positive effects may depend on the *quality* of basic research or the *quality* of researchers co-operating with industry. The industrial sector of the co-operating firm, its R&D intensity or its human capital structure may also have an impact on changes in the area of public research.

A more general question is whether industry funding of higher education "R&D" is the correct metric for assessing the impacts of university engagement with industry. As stated at the beginning of this paper, the relationship between HEIs and businesses has been focused on the research link, i.e., the R&D connection and therefore, the role of businesses funding higher education R&D. The educational linkages between HEIs and industry may be a more fruitful area for studying the effects of industry and academic co-operation from the standpoint of the knowledge triangle.

Another issue concerns the nature of the links between HEIs and industry and the effects these may have on research areas. Industry-science relations are often stronger in some fields (e.g., engineering, ICTs, life science) than others (e.g., sociology, political science). Indeed, research has found that departmental differences have an effect on the extent of Italian HEIs' engagement with third party funding [*Bonaccorsi et al.,* 2014]. In the US, medical sciences and engineering departments receive much more funding from the business sector than other academic fields. At the same time, as industry funding is usually channelled through contractual agreements with explicit objectives, there is a risk that industry funding could reduce the autonomy of institutions and result in shifting public research towards more applied research. Although this has been a long-standing concern, the available evidence on this is not conclusive, despite some evidence of HEIs' increased inclination to undertake applied research.

International sources of funding

International funding also has important implications for the steering and performance of research. In the European context, supranational funding for research through the EU's Horizon 2020 programme is not only an important source of research funding, but it also shapes and "influences" national research agendas, notably through its emphasis on operational research funding directed towards the grand challenges. This in turn has an impact on the bottom-up orientation of research at HEIs. Similarly, the EU's Smart Specialisation Strategy provides an additional source of funding from EU structural funds that is used for research infrastructure and human resource development at the regional level. In smaller EU countries, this funding is a large source of HEI funding, representing 24% in the Czech Republic, for example [*Kostic et al.,* 2016].

Other, non-governmental research funding schemes

Foundations, alumni, wealthy individuals, charitable trusts and crowdfunding are increasingly important and growing sources of research funding for HEIs. Philanthropic funding accounts for almost 30% of the research funding of leading research universities in the United States and represents more than US $4 billion a year [*Murray,* 2012]. The United Kingdom is another example of where philanthropic funding represents a notable share of the revenue of HEIs. Some research universities in the United Kingdom earn almost 10% of their total income from philanthropic sources [*Estermann, Pruvot,* 2011]. Philanthropic funding is partially encouraged by the policy of the UK government to provide additional research funds to HEIs depending on their charity income; the charity support funding was approximately £198 million in 2015–2016 [HEFCE, 2011].

Autonomy in financing

The diversification of funding sources and channels might have a direct bearing on the autonomy of HEIs. Firstly, more diversified funding sources and channels of HEIs may imply that they are less dependent on a specific funding channel, particularly on government funding; which provides HEIs with a sense of increased autonomy in research and education. This kind of argument is often used to encourage HEIs to make efforts to diversify their funding sources. However, in a context where the diversification of funding sources is usually accompanied by an increase in competitive-based funding and contractual arrangements, the effects of funding diversification should be analysed using empirical evidence.

The more autonomous HEIs are in financing can potentially enhance the diversification of funding channels as HEIs try to enlarge their sources of funding. This aspect can raise an issue for policymakers about the degree of autonomy that should be granted to HEIs. Currently, the authority of HEIs to make important decisions on financing varies across countries. For example, universities in Italy, Portugal and the UK can decide the level of tuition fees under a ceiling, which is decided by governmental authorities, while the government sets the fixed amount of tuition fees in France, the Netherlands and Spain. Furthermore, autonomy in financing encompasses various issues concerning one's ability to retain a potential surplus from state funding, the ability to raise money on financial markets and the ownership and sale of real estate [*Estermann et al.,* 2011].

Place-based policies and HEIs: Challenges, obstacles and open questions

In a place-based context, municipal governments must invest in the knowledge base of HEIs but they must also encourage cooperation between HEIs and the local ecosystem in order to encourage firm competitiveness and structural change through new firm growth. However, in many countries, higher education and research policy lacks an explicit territorial dimension. Academics and their universities are generally rewarded on the basis of the quality of their research activities or whether they collaborate with businesses, irrespectively of where companies are located. The lack of an explicit territorial dimension is often reflected by funding and incentive mechanisms defined by national agendas that generally provide little support for regional engagement. In some cases, there might be a lack of co-ordination at the government level: ministries or departments responsible for higher education and research might tend to promote a national or even international excellence agenda, at the same time the departments responsible for territorial development might encourage universities to maximise local knowledge spillovers.

An additional challenge in promoting regional engagement is the lack of appropriate and reliable metrics. The impact of regional engagement is difficult to measure. It is very challenging to measure how much HEIs have impacted the regional and local economic performance after the fact. Evaluation practices for research and education activities — instead — are much more well-established. For this reason, evaluations of HEIs often take these two missions into account and only partly consider the third mission or regional engagement.

Whether to expect most institutions to undertake all forms of academic activity including research, teaching and community service or to designate some as mainly teaching-only institutions and to concentrate research in a few world-class research-intensive institutions is an open question. Depending on the region, the critical mass of researchers, the economic specialisation as well as other factors, different HEIs' profiles and strengths may benefit the local ecosystem in different ways. In addition, on the local demand side, even if a leading university is located in a particular region, there may be limited absorptive capacity in local enterprises, especially SMEs or the branches of multinationals that do not perform local in-house R&D activities [*Goddard, Puukka,* 2008].

To overcome some of the challenges described above, some countries have introduced "third-mission"-related activities in the performance contracts between the state and universities. In Austria, 15 out of 22 public universities agreed to introduce elements of place-based innovation in their three-year performance contracts. This strengthened the role that universities played in the design of Smart Specialisation Strategies in Austria [OECD, 2014].

Boundary-spanning organisations such as "technology transfer offices" and "research and development units" within universities themselves have often been encouraged and supported by regional and national policy initiatives. Regional governments, in particular, have adopted many initiatives to establish "intermediary bodies" to act as a catalyst between universities and businesses to incentivise their collaboration. The European Institute of Technology (EIT), which is promoted by the European Commission, is just one example of such an initiative at the European level.

Capacity building in regional innovation systems requires not only the research and talent in universities (generative capacity), but also an absorptive capacity in the private sector and clusters; a collaborative capacity in networks, associations and joint facilities; and a leadership capacity from boundary-spanning organisations with a guiding vision. Improving innovation systems at the local level can be hampered by, among other things, a lack of political leadership on the part of the local government, low demand from the private sector, narrowly focused academic research and teaching at HEIs, and a lack of "boundary-spanning" organisations. For these reasons, traditional place-based policy approaches have largely underestimated the educational role of universities and other HEIs in strengthening regional innovation ecosystems and fostering structural change [OECD, 2015].

Given the large heterogeneity of regional innovation ecosystems and the importance of place characteristics for the innovation process (reviewed in the first section), place-based innovation policies in support of the KT seem well-warranted. The diversity of regions, their various levels of economic development, and industrial specialisation all call for tailored approaches.

Third mission activities

Knowledge exchange and community engagement are long-standing characteristics of HEIs in most OECD countries. However, during the move towards increased autonomy and accountability for most countries' HEIs, many states have acted to strengthen and formalise the social and knowledge transfer role of HEIs. In Sweden, for example, the third mission is officially recognised as a mission of HEIs in the Higher Education Act. Third mission policies therefore partially represent a more active state role in reorienting higher education towards social concerns and innovation. Some countries have dedicated innovation funding schemes to encourage knowledge exchange activities such as interaction with small- and medium-sized enterprises (SMEs). Some OECD countries have also made efforts to measure and record collaboration and dissemination activities. Such policies can also be seen as a response to the "innovation paradox" and concerns in many countries that high-quality research has not been translated into innovation performance [IPP, 2015a].

As a result of increased policy attention, these activities, or at least their measurement, may have become more widespread. For example, Marginson and Considine [*Marginson, Considine,* 2000] remark upon the increase in community service and engagement among Australian universities since the 1990s. However, another reason for the increase may be that certain collaboration activities provide an important revenue stream for HEIs. Income from contract research, for example, has become an important source of income for a number of HEIs [OECD, 2008]. Some countries have attempted to increase the capacity of HEIs to engage in knowledge exchange activities by providing dedicated funding (see, for example, the Innovation Policy Review of Sweden, [OECD, 2013]). A detailed evaluation of knowledge exchange funding for HEIs in England found that the policy has generated significant additional knowledge exchange income for institutions, as well as strengthened aspects of the link between teaching, research and knowledge exchange [HEFCE, 2009].

Policy contradictions and open questions

Many governments are interested in enhancing HEIs' contributions to the innovative process, economic growth and social development. Rather than being seen as separate missions, education, research and innovation should be seen as part of an overall system encompassing a range of economic and social objectives. Research policies, education policies and innovation policies can be mutually reinforcing, but country diversity shows that there is no single model for alignment. Policies designed to promote innovation directly can have adverse effects on those that promote innovation indirectly. In the context of the knowledge triangle, these interrelationships are an important consideration for policy and governance mechanisms concerning HEIs.

A key issue from the perspective of the knowledge triangle is the potential complementarity or trade-off between the different missions of HEIs, and the implications for innovation. Some of the broad changes affecting STI policy and HEIs can have a number of effects on these relationships. The following section sets out some potential and tentative implications.

Tensions between universities and PROs

In many OECD countries, the focus on universities as hubs of knowledge creation, entrepreneurship and innovation has challenged the traditional division of labour between universities and government labs or institutes that fall under the broad heading of "public research organisations". PROs often undertake longer term research that goes beyond the 3- or 5-year funding cycles that are typical for research programmes at universities. In some cases, institutes have been merged with universities (e.g., the Rosline Institute at the University of Edinburgh). While the trend of transferring labs to universities helps in retaining knowledge creation capacity, this can also create tensions between academic departments which must seek short-term competitive funding and centres and institutes which have ring-fenced funding.

Potential trade-offs in knowledge production and diffusion

The increased commercialisation-based and profit-seeking attitude associated with financial autonomy may have competing effects on an HEI's research activities. For instance, a push for commercialisation could impinge on an HEI's willingness to extend informal expertise. Faculty that could earn money from consulting activities might also have fewer incentives to engage in community outreach. The formalisation of knowledge transfer activities creates benefits but also problems for companies. For most HEIs, informal and formal linkages with industry, as well as student and staff mobility, are the most important sources of commercialisation and knowledge transfer [OECD, 2011]. Increased industry-HEI collaboration and the formalisation of knowledge transfer raises the potential risk of negative effects on basic research spending, scientific inquiry for its own sake and the free dissemination of discoveries would decline [*Mendoza,* 2015]. More speculatively, the incentives created by research funding schemes oriented towards academic excellence could potentially discourage activities linked to the third mission unless there were strong monetary or altruistic incentives to perform these activities in place. At the very least, faculty are limited in the amount of time they can devote to third mission activities insofar as career advancement depends more on publishing and teaching. At the same time, a more competitive and market-driven environment may encourage HEIs to build linkages with external partners as a potential source of research funding and income. Linkages with industrial, government and community partners can be a source of ideas for researchers.

Relationship between education and research

Debates over the relationship between research and teaching are long-running. There are reasons for teaching and research to be complementary: knowledge of up-to-date research can improve the quality of education and the relevance of investments in human capital, while the movement of students into the workplace allows knowledge from research to be disseminated more effectively. Feedback to research universities from students and prospective employers can help maintain the social relevance of research. Yet the long-running increase in the rewards to research relative to teaching is often argued to have weakened the relationship between the two. Empirical evidence at the student/academic level, predominantly in the United States, tends to find no or limited evidence for a positive relationship between research productivity and teaching effectiveness as judged by students [*Centra,* 1983]. The research-intensive units that are most successful at winning competitive grants, such as medical schools, may not be responsible for extensive education and training. In addition, if research increases in complexity over time it may become less closely connected to education. The nature of the relationship between education and research is likely to vary by the fields of science and education.

Relationship between education and the third mission

Similarly, a number of factors could affect the relationship between third mission activities and education. Interactions between researchers and industry or the local community can help them relate their research and teaching to real-life problems. Vocational education colleges, in particular, may face the challenge of keep their programmes up-to-date with technology and innovation [*Toner, Dalitz,* 2012]. Thorn and Soo [*Thorn, Soo,* 2006] show how a "third-mission" orientation has had spillover effects on the advanced training activities of universities in Latin America (e.g., real-life problems in university courses and collaborative doctorate research projects). Education can affect innovation too: Thune and Børing [*Thune, Børing,* 2014] show that the industry placement of doctoral degrees is used by firms for a range of purposes including developing broader competencies, knowledge in core technological areas, R&D competencies and innovation capabilities. However, here too there could be negative effects. One concern is that an outward-looking focus encourages HEIs to focus education and training on short-term employer needs, and potentially become less well-aligned with the unpredictable skill needs of the future. The impact of industry-academia linkages on students requires more research [*Mendoza,* 2015]. The governance mechanisms associated with the formalisation of the third mission, such as performance agreements and new evaluation methods, may also have their own effects on teaching and training.

Fragmented governance

At the national level, policy co-ordination is important for organising and implementing the policies towards education, research and innovation. In many countries, policy co-ordination takes place through inter-ministerial councils or through more informal means such as strategy documents and white papers. At the regional level, economic development agencies also exert an influence on HEI activities. The corollary of greater autonomy is that the task of co-ordinating and integrating the multiple missions of universities falls on the institutions themselves. However, the silo model of funding and regulations for the different missions do not facilitate these tasks for institutions. This altogether places large expectations on universities to align their missions and create interactions between these different tasks [*Benner, Tushmann,* 2015]. This results in a dual and at times fragmented governance system whereby institutional choices are determined by internal governance structures (e.g., rectors, faculties and departments) that are only partly influenced by national policies (legislation, funding) or regional actors. Furthermore, governance mechanisms such as performance agreements and evaluation criteria may inadvertently include a bias towards one or another element of the knowledge triangle.

Place-based and HEI ecosystems

HEIs are important employers and service providers that are an integral and permanent part of most regional economies. In some regions, co-operation between universities and external partners has a long history and has been supported by existence of industrial and scientific infrastructure in the region (e.g., science and technology parks) as well as clusters and regional support structures to foster innovation. In others, this collaboration was promoted by (supra-) national or regional-level policies and by the availability of increased funding to foster research, innovation and knowledge transfer. The availability of public funding programmes aiming directly at the exploitation of research results and at closer linkages between universities and companies has also brought regional governments and HEIs closer together. However, while HEIs are increasingly engaging local stakeholders on university boards or for fund raising, the corollary is also important. Economic development agencies can arguably do more to engage HEIs in their public service delivery missions, economic development, urban planning or "smart city" initiatives [*Meissner,* 2015a,b; *Schiavone, Simoni,* 2016; *De Grande et al.,* 2014]. The role of HEIs in the regions also depends on the relative power and motivation of the actors. In a government-pull model, entrepreneurial universities assist the development of existing industries and the creation of new industries in response to incentives from the government, such as budget funds. In an industry-pullmodel, universities respond to opportunities for cooperation with industry on specific problems.

Conclusion

Higher education institutions (HEIs) play a central role in the innovation systems of OECD countries. Much of the government funding that is channelled for education and research is performed by HEIs. Firm innovation increasingly relies on the science base that is generated at HEIs as evidenced by data on patent-science linkages and industry-university collaboration. HEIs are also major employers of researchers in OECD countries and provide services to local and national economies. In addition, HEIs provide many public goods to society from knowledge spillovers and well-trained graduates to scientific recommendations for policymakers as well as private goods such as consulting services, patented inventions and contract research. For these reasons, an understanding of how national policies and institutional practices can enhance the contributions of HEIs to society and the economy is critical.

In light of the decentralisation of the funding for HEIs in many countries and high competition for support for research projects, these institutions currently experience colossal pressure from the government and other stakeholders. In order to meet modern requirements as well as the demand for more inclusiveness and accessibility, higher education institutions must be reformed. Raising the social and economic significance of HEIs is a key point of national policy, which requires new approaches. Therefore government agencies in the OECD place great hope in the knowledge triangle concept, which aims at exploring ways to better align and integrate the research, education and innovation functions of HEIs via national policies and institutional activities. Traditionally, the linking of research to innovation has been encouraged by governments and industry. In addition, at HEIs with a Humboldtian tradition (e.g., in Germany, the US and Northern Europe) the linking of research to education has been well established since the 19th century. However, this link continues to evolve as governments channel greater amounts of research funding to HEIs. In contrast, the links between education and innovation have been less a focus of national policymakers or institutional leaders until recently.

The novelty of the knowledge triangle framework is that it encourages mechanisms to link education to innovation *via* entrepreneurship, for example, or innovation to education and research, for example, by permitting professors of practice from industry to lecture at universities. The goal of knowledge triangle-targeted policies is to generate qualitative and quantitative effects from these interactions that are greater than sum of the individual outputs of HEIs (e.g., academic articles, graduates or academic patents, local employment effects).

However, HEIs are diverse actors with diverse missions. The "optimal" structure of HEIs in relation to innovation is likely to vary across countries. It follows that there is no single model of HEIs or of the knowledge triangle. A range of different types of HEIs can contribute to innovation via their education, research and other activities, in conjunction with other actors. For example, while leading universities may excel in the number of highly cited academic articles and academic patenting, small teaching-only institutions can also play an important role in developing the technical, creative and managerial skills that contribute to innovation in the surrounding regional economy.

Yet, despite the diversity of HEIs, data shows that education, research and innovation activities at HEIs are concentrated within a few large institutions in OECD countries. Concentration may reflect a combination of historical factors, size-scale factors, but also government policies, such as performance-based contracts and increases in research funding relative to education, etc. New institutional policies related to new public management ethos that raise institutional profiles or recruit "star" faculty to attract additional funding for students, research and business collaboration would strengthen competitiveness.

The conclusion is that there is no single model of universities and the knowledge triangle. This is due to the country-specific peculiarities of educational systems, diversity within HEIs and the functions they perform, as well as the specifics of regional ecosystems. Accordingly, the key to the efficiency of the knowledge triangle tools is their place-based adjustment. In order to achieve a tangible contribution by universities to the development of regional and local innovation, it is necessary to ensure complementarities and balance between their missions.

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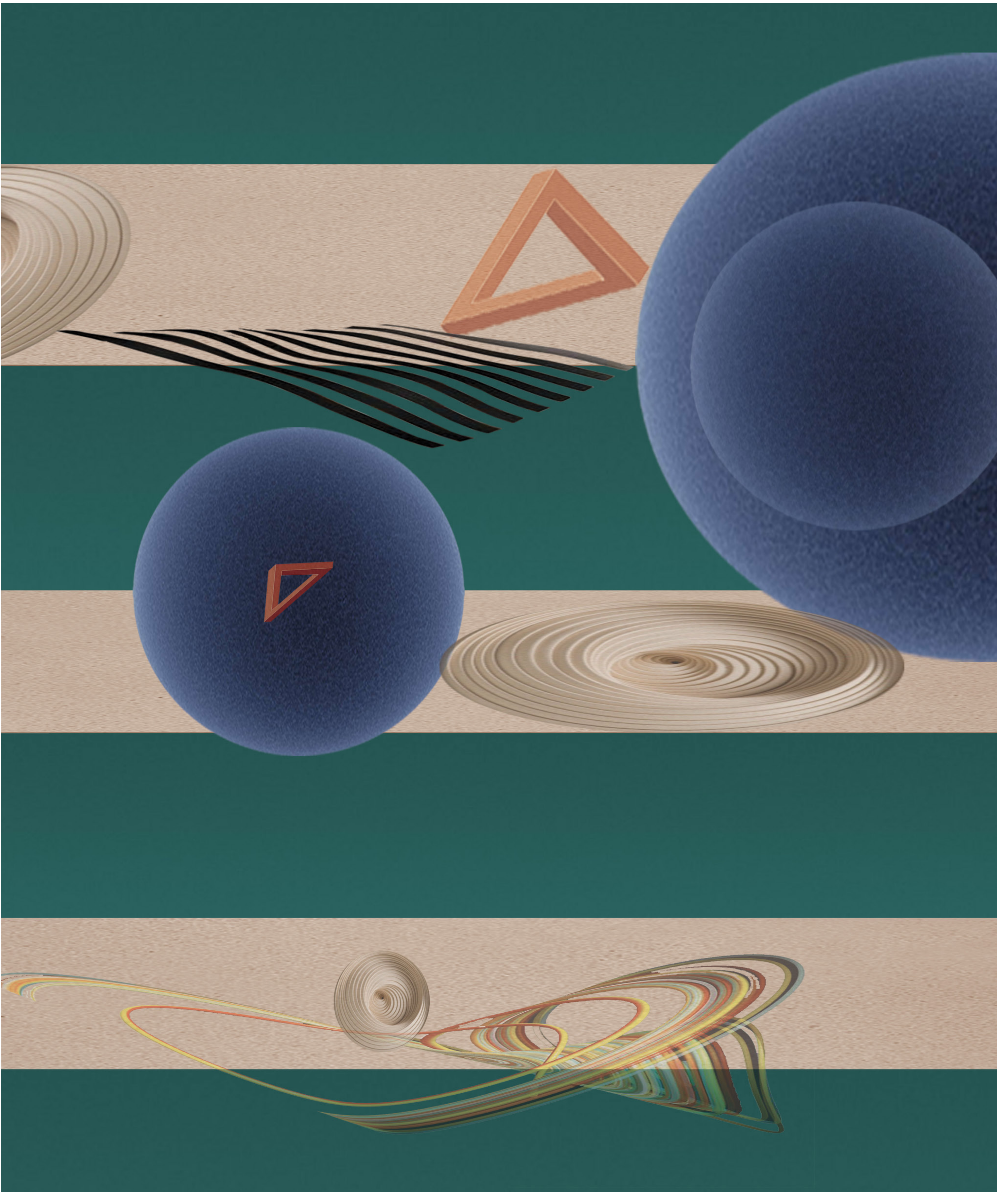

How Will Open Science Impact on University–Industry Collaboration?

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Abstract

Open science represents a challenge to traditional modes of scientific practice and collaboration. Knowledge exchange is still heavily influenced by researchers' ambitions to publish in highly cited journals and within "closed partnerships", where interactions are based upon intellectual property rights. However, perceived inefficiencies, a desire to make publicly funded research available to all and a crisis of confidence in the quality of research published in top journals all serve to fuel demands for more openness in the conduct of science and the exchange of scientific knowledge. Whilst there is a strong logic behind the contention that increased openness will promote efficiencies, quality and fairness, there is still considerable uncertainty about the impact on university-industry collaboration and the balance that needs to be struck between open and closed approaches. Policy obstacles are also likely to impede the pace of change.

Keywords: open science; open access; knowledge exchange; university/industry collaborations; science policy; research funders.

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Calls for research to be made "open" are gaining momentum. Funders have been particularly active in demanding change. Although they vary in the degree of openness required and in their interpretation of what a more open approach actually entails, there is now a near consensus that, at the very least, open access must apply to published research results and some funders increasingly require access to research data as well. In addition to funder requirements, other drivers of increasing openness include calls from a variety of stakeholders including researchers themselves for more transparency and less duplication in research.

It is too early to give a definitive answer to the question posed in the title of this article. However, asking the question at this time is a useful exercise as it encourages us to reflect upon the current situation and begin to analyze current trends, drivers and enablers related to open-science-based collaboration as well as obstacles and tensions associated with open and global access to science. This article endeavours to begin that work and to identify some of the policy challenges associated with moves towards more open science. The study is structured around a number of sub-questions to the title's overall question and concludes with some reflections on the implications for policy-making.

Are we moving away from traditional models of S&T-based university-industry collaboration?

Over the course of the past century, the professionalization of science has seen been associated with the emergence of specific organizational and institutional centers of scientific activity. Scientific activity has overwhelmingly taken place at universities or other research organizations, government laboratories or at research and scientific facilities supported by private companies. Norms have emerged that provide the basis for career development and incentives and have also come to define "excellent" research. The infrastructure of knowledge-generating and -diffusing institutions provide a powerful embodiment of Western science's ambition to produce more of this knowledge. The world's best universities and leading scientific journals have reflected a deeply engrained understanding of how excellence is produced and how it is shared [*Chataway, Smith,* 2007].

Patterns of interaction and knowledge exchange between organizations and institutions have also been underpinned by well-established norms and increasingly in R&D-intensive sectors, by intellectual property rights. There have been periods and specific instances of data sharing and collaborative approaches, which run counter to the usual restrictions on ownership and governance structures, but these have usually been associated with security issues and national emergencies. Outside of these particular circumstances and periods of time, for the most part the extent to which data have been generated or shared has been regulated by professional norms and by various forms of copyright and intellectual property protection. Collaboration between companies and universities has increasingly been built upon IP agreements and other mechanisms to facilitate partnership in order to protect investments made during the early stages of research [*Arora, Athreve,* 2012].

The premise of these arrangements is that universities produce scientific knowledge that, once patented and perhaps published in leading journals, can be transferred and commercially exploited by new or existing companies. A recent article described this era of knowledge transfer and exchange as "closed partnerships" [*Holmes,* 2016] and argued that this arrangement was typical in the 1980s. However, this formula has been modified in recent decades, supplemented with other forms of partnerships and in some cases replaced with more open arrangements [*Ibid.*]. The closed exchange model is no longer assumed to be the most efficient way of sharing results. Furthermore, the debate about the impact more open science might have on university and industry relations points to several areas where the evidence is ambiguous and uncertain.

First, a number of academics and analysts have pointed out that the majority of innovation does not depend on outputs from R&D [NESTA, 2007]. Most changes in patent restrictions and open access approaches that reveal early research findings in an accessible way would not have a negative impact on the interactions between universities and industry, in the sense of a decrease in the quantity or quality of exchanges, because tacit knowledge is and always has been at the heart of successful relationships [*Nelson,* 2004]. In addition to this, there is a mounting of body of evidence that questions whether the traditional model is actually the most efficient way of organizing the production of scientific knowledge and whether it is effective in underpinning product development and innovation. We will look briefly at two areas where there has been a critique of restricted access to knowledge. The first area relates to intellectual property rights (IPR) and the second concerns access to publications.

What is the impact of IPR on innovation? Do the tragedy of the anticommons and perceived inefficiencies outweigh the benefits?

The use of IPR has been an important component of innovation policy for many years. The history of IPR and innovation policy is long and complex. It is not our intent to review or summarize that history here. Our aim is limited to highlighting the increasingly contentious notion that patenting, especially as it applies to early research results and tools, fosters innovation. Most of our examples are from the life sciences field. This is the sector where the debate about patenting has been the most intense and it is a sector where experimentation in open science and open innovation is particularly evident.

In recent decades, the rate of patenting has increased significantly across a range of sectors and particularly in the life sciences [*Owen-Smith, Powell,* 2003; *Bubela et al.,* 2013]. The causes of this rise in patenting activity are complex and differ somewhat across sectors. One of the drivers behind the move to early patenting in both the public and private sectors is increasing financial pressures [*Morgan Jones et al.,* 2014]. In areas such as biotechnology, innovation is largely rooted in industrial structures that depend on patent-backed finance and this has fuelled what some analysts consider an unproductive tendency to hype patented research results and tools, which subsequently lead to investors becoming disillusioned with the sector [*Hopkins et al.,* 2007; *Owen, Hopkins,* 2016].

A number of authors have questioned the effectiveness of patenting at an early stage more generally [*Marshall,* 2012; *Eisenberg,* 2012], noting that patenting may reduce incentives and capacities to share knowledge. Michael Heller deploys the term "the tragedy of the anticommons" to refute a longstanding contention that common property will be neglected and will not generate the expected returns to a community over the long term [*Heller,* 1998].

In more recent years, the modeling of anti-commons behavior has been used to dispute the efficacy of patenting across a range of sectors including biotechnology [*Burk, Lemley,* 2009; *Heller,* 2016]. Nelson [*Nelson,* 2004] argues that technological advancement is an evolutionary process, and as such, benefits from the development of knowledge via multiple pathways by a number of different actors. It is also cumulative, as bodies of knowledge build on previous understandings. The scientific community, Nelson claims, should not be hindered in working freely with and from new scientific findings because of the long-term and public good benefits that come to society from investment in basic research.

Patents on early stage research, in particular, can prove costly and bureaucratic, and this has direct as well as less obvious impacts on the rate and direction of research. One of the less obvious consequences is that researchers may need to weigh the costs of accessing tools and techniques to enable them to undertake research and this makes them more risk-adverse. This is a problem for both public and private sector scientists.

Although IP provides a route for start-up companies to raise financing and is therefore seen by many as enabling innovation, the impact of reliance on IP for financing also constrains what companies are able to do [*Tait, Chataway,* 2007]. This has led proponents of open science approaches to question the degree of risky innovation that organizations, which are highly dependent on patenting, can undertake. Aled Edwards from the Structural Genomics Consortium says:

> *Industry scientists do not have the opportunity to focus their efforts on discovering new validated targets and mechanisms. More often, they develop innovative ways to tackle established ("validated") drug discovery mechanisms. This situation arises because there is a disconnect between drug discovery timelines (5-10 years) and the need for biotech investors to recoup their investment (2-5 years)* [*Edwards,* 2013].

Edwards concludes that because biotech firms are dependent on IP-related finance, they can never be the source of more radical and risky innovation.

Should we be concerned about the efficiency and quality of mainstream science?

A paper appearing in *Nature* in 2012 [*Begley, Ellis,* 2012] by researchers from the pharmaceutical company, Amgen, raised a set of concerns about the quality of science being produced in top journals and the extent to which that "excellent" science could actually be used in innovation and product development. The article reported that a large percentage of cancer-related studies that Amgen researchers tried to replicate were not reproducible. Begley and Ellis question the incentive frameworks that academics work within and question whether peer review is an effective mechanism for assessing the quality of scientific output and evaluating grant applications. The authors suggested that bad practice are not checked and may actually be encouraged under the current system: "*…the academic system and peer-review process tolerates and perhaps even inadvertently encourages such conduct. To obtain funding, a job, promotion or tenure, researchers need a strong publication record, often including a first authored high impact publication. Journal editors, reviewers and grant giving-review committees often look for a scientific finding that is simple, clear and complete — a 'perfect' story. It is therefore tempting for investigators to submit selected data sets for publication, or even to massage data to fit the underlying hypothesis*" [*Begley, Ellis,* 2012]. Even diligent peer review commissioned by the best journals will not be able to detect the problems that arise from this behavior.

In an introduction to a recent series of papers on increasing value and reducing waste in healthcare research, the editors of *The Lancet*, a leading healthcare research journal, reflected on Randy Schekman's critique of standards in "luxury" journals such as *Nature*, *Science* and *Cell*. According to Schekman, a Nobel prize laureate, the reputations of these journals rest upon the unwarranted notion that they publish uniformly excellent research. He asserted that they are far from the only outlets for outstanding research. *The Lancet* editors produced a special issue that tried to look more broadly at the following question: "How should the entire scientific enterprise change to produce reliable and accessible evidence that addresses the challenges faced by society and the individuals who make up those societies?" [*Kleinert, Horton,* 2014].

One of the articles in the special issue analyzes the cost of R&D and the losses associated with conventional methods of producing knowledge. Costs associated with R&D have risen annually and current expenditure on a global basis was estimated at US $240 billion a year in 2010 [*Chalmers et al.,* 2014]. Basic research is the principle beneficiary of this investment. More than half of £1.6 billion of public and charitable investment in research in the UK was spent on basic research in 2009-2010, and this pattern was also observed in the US. While researchers often want to work on basic research and "luxury journals" want to publish breakthrough findings, there appears to be strong evidence emerging that basic research is not responsible for major successes in medical innovation in the way that earlier analysts assumed that it was [*Chalmers et al.*, 2014]. In 2009, Chalmers and Glasziou estimated that the cumulative effect of avoidable losses in biomedical research means that about 85% of research investment — equating to $200 billion of the investment in 2010 — was spent ineffectively [*Chalmers, Glasziou,* 2009]. Using a narrower measure of waste, Freedman et al. estimate that the cost of the lack of reproducibility in life sciences is $28 billion [*Macleod et al.,* 2014; *Freedman et al.,* 2015]. The complex set of factors that produces this situation is related to an incentive structure that promotes secrecy, a lack of openness and a fixation on publishing in high-impact journals.

What is open science and might it help produce scientific knowledge more efficiently and effectively?

There are changes taking place that may help counteract some of the problems associated with our current "conventional" modes of performing and rewarding research. This transformation is happening across the whole research process, from the way public research agendas are set to the way results are shared with other researchers and the public. These changes are neither uniform across the research process nor are they equally shared amongst disciplines, but collectively they appear to be having fundamental effects on the research system. Together, these changes are often referred to as *open science* and they represent what might be best described as a movement of researchers and others involved in scientific research, that, in some respects, runs counter to, but is also effectively evolving from the traditional model of scientific research.

Open science is most frequently and closely associated with *how* research is conducted and *how* the results are disseminated. Open access to scientific publications is the most well-known aspect of the open science movement, whereby research outputs — typically journal articles — are made freely available, without access fees and increasingly with fewer copyright and licensing restrictions. As an example, Randy Scheckman, the Nobel prize winner mentioned earlier, has since established an online open access journal that defines itself as existing outside of the framework assessing impact factor.

Worldwide, the proportion of papers published with open access in 2011 was about 44%, up from 38% in 2004, taking this practice well into the mainstream of research [*Archambault et al.,* 2013]. Many researchers and increasingly policymakers aspire to open access becoming a standard feature of the research process [Netherlands EU Presidency, 2016]. The EU Competitiveness Council has already concluded that all scientific articles should be open access by 2020 [Council of the European Union, 2016].

Open science also refers to an increase in researchers making the data underpinning research results freely available online. Some of the most prominent examples have emerged from large-scale public health crises. For example, data sharing of genome analyses to tackle the Ebola epidemic was widely seen to have enabled geneticists and evolutionary virologists to work together to confirm the origin and transmission mode of the virus as well as the estimated routes of infection and predicted rates of mutation. This information supported crisis management efforts by local and international public health organizations by showing them where to focus their relief efforts and enabling them to develop practical advice to limit the spread of infections. Data sharing also helped both the public and private sectors to more quickly design new therapies, diagnostics kits and vaccines. Besides Ebola[1], similar efforts have been undertaken to combat the Zika virus outbreak and malaria.[2] Indeed, there is emerging evidence that where data sharing failures do occur, progress in addressing the problem is slowed or hindered, as demonstrated during the outbreak of Middle East respiratory syndrome (MERS) in Saudi Arabia, where disputes over intellectual property rights created barriers impeding access to samples [*Yozwiak,* 2015].

Online repositories have emerged in recent years to collect and make researchers' data available. Zenodo is an example at the other end of the spectrum from the international efforts to address the major diseases cited previously, focusing instead on the "long tail" of small-scale research results that are not otherwise part of existing institutional repositories. Zenodo invites submissions from any discipline and particularly encourages multidisciplinary contributions.

Researchers have also increasingly begun to share their code, software, and lab books. For example, GitHub has become an important source of open code and for the development of open software, citing

[1] www.eboladata.org.

[2] www.opensourcemalaria.org.

15 million users across 38 million records on the site[3]. The overall effect of this "opening up" in the research process means that researchers are communicating more freely and transparently and at earlier stages in the research process, to generate new ideas, find collaborators, define research methodologies and analyze their results. This should lead to the greater use and reuse of data, the earlier identification of problems, and improved and more rapid development of research tools. This may well mean that open science can address some of the challenges with as much efficiency as the traditional, mainstream model.

Open science can also resolve problems associated with low reproducibility and poor quality that can occur through more traditional research approaches. Open peer review can include a disclosure of information about the peer reviewer (as opposed to anonymization) and a publication of the contents of the review. Open peer review can also refer to allowing unsolicited peer review. Alongside more freely available data and access to research results, being able to assess the contents of a peer review could help others identify the bad practices and "too perfect" stories that can be told when this information is not available. Online forums and social media allow scientists to quickly uncover high-profile studies with major underlying flaws, such as the "discovery" of arsenic-based life [*Hayden,* 2012].

Other initiatives aim squarely at the problems associated with the lack of reproducibility identified in many disciplines. A leading example from psychology, the Reproducibility Project, involved 270 scientists in trying to reproduce the key findings of 100 articles published in three leading psychology journals, which found that only 30–50% could be replicated [*Aarts et al.,* 2015]. From the perspective of "opening up" the scientific process, this project not only prioritized correspondence and collaboration with the original authors, but also encouraged the authors to publish the results in an open access format and made the underlying datasets available for others to use in the future. A similar effort is being undertaken in other disciplines, such as cancer biology, with the effect of highlighting the importance of replication in the advancement of science. Innovation is important, but without replication one cannot verify new findings, and therefore we can never be certain whether we actually "know what we think we know" [*Ibid*].

A final potential corrective to the traditional model of scientific research enabled through open science is increasing the support given by non-professionals and multi-disciplinary researchers during the research process. Crowdsourcing is the archetypal example whereby an often undefined set of people — the "crowd" — is called upon to help solve problems or contribute to other aspects of the research process, including correcting mistakes and raising money. This support may range from generating research ideas to data gathering, problem-solving and decision-making either in a collaborative way or through independent contributions. Foldit is one example, involving an online game about protein folding; the highest scoring submissions are analyzed by researchers to determine whether the configuration is applicable to proteins found in nature. A study of the outcomes of the Foldit approach, published in 2010 [*Cooper et al.,* 2010], found that the solutions identified by gamers were better than those generated by a computer algorithm. The solutions could be used to develop new biological innovations or cure diseases.

In many cases, the people who participate in these projects would not traditionally be considered "experts" in the field to which they are contributing, while in others, crowdsourcing enables the engagement of researchers who may not otherwise have had the opportunity to participate. The Reproducibility Project is one such example of the latter. In most cases, participants are recruited online through an open call. This reduces the logistical problems associated with having participants travel to a centralized location and enables the call to reach a wider set of potential participants.

Proponents of open science argue that these activities can increase transparency, collaboration, communication and participation in scientific processes. They could help remove disciplinary barriers and encourage greater interaction between "science" and "society". They could also speed up the scientific process by tapping into the critical mass necessary to generate ideas, increase the efficiency of the process, and facilitate the validation or rejection of theories.

Digital technology enables many of the developments that are considered part of open science, but technology alone is not responsible for the size and scale of activities in this area. Open science is also strongly supported by those who believe in the value of freely circulating knowledge and freely circulating critiques of that knowledge, and interest in the role, value and function of data in the research process.

Are we moving towards a new era?

The dynamics between advocacy, technological progress and institutional change are interesting to consider when reviewing the progress of open science. The power of advocacy and social movements is a key factor in health innovation. The history of drug development is full of examples of progress rooted in the advocacy for patients and patient organizations [*Chataway et al.,* 2010; *Marjanovic et al.,* 2015]. The targeted allocation of resources and incentives for organizations to work together resulted in significant investments in the treatment of HIV/AIDS and for certain kinds of cancer [*Taylor et al.,* 2015]. Whilst the momentum behind open science grows, evidence concerning the costs and benefits lag behind. The

[3] https://github.com/.

extent to which open science will transform relationships is likely to depend both on the strength of advocacy and evidence in a number of areas.

What is the optimal balance between openness and ownership?

The issue of whether various forms of open science contribute to more effective science (improving the rate of output) or to more efficient science (improving the external effects or, in other words, the degree to which that science is used by target audiences) will be important in determining the extent to which it takes root institutionally.

Some benefits of open science are easier to calculate than others. The value of data repositories has been examined and studies suggest that its economic value is clear [Lateral Economics, 2016]. This still leaves ambiguity, however, with regard to the extent to which open science and innovation are associated with economic efficiency and value creation. The evidence on that assertion remains unclear. It is true, however, that there is a clear logic that argues for more efficiency in many cases. In drug development, where patenting is still the norm and where the costs of research are so high, the argument that open science could reduce duplication is particularly convincing. A more open approach would reduce the extent to which companies conduct identical or similar research behind closed doors. This is particularly important because companies tend not to publish failed studies. This means that other groups are likely to follow the same routes of enquiry without knowledge of the previous unsuccessful attempts.

On this point, Pierre Meulien, head of the Innovative Medicines Initiative (IMI), is quoted in *Nature* as saying: "If ten companies are working on Alzheimer's disease on exactly the same target and it's failed, that's ten times the investment that is down the tubes" [*Savage,* 2016]. This duplication and unproductive replication of research may well underlie much of the unjustified losses identified by Glasziou and Chalmers in a study referred to earlier in this article [*Glasziou, Chalmers,* 2009].

Many proponents of more open approaches feel that the most significant contributions of open science will come from knowledge gains. Sharing the investments and opening channels for knowledge exchange will lead to a greater understanding and the generation of research results in areas that were previously deemed too risky and expensive [*Morgan Jones et al.,* 2014; *Savage,* 2016]. Moreover, open partnerships facilitate greater knowledge exchange between public and private sector researchers, each of whom bring a different focus to the science and development of research [*Morgan Jones et al.,* 2014].

If the logic behind the arguments that more open approaches will generate overall benefits, particularly in the early stages, seem strong, an important question still remains concerning how economic benefits from research will be shared. This issue becomes more acute at later stages of applied research, when in drug development, for instance, research costs rise dramatically. Members of the SGC team have tried to develop more downstream approaches and have had much more difficulty in making openness work in this context [*Savage,* 2016].

While an evidence base is emerging to help us identify the benefits of more open approaches, there remains a great deal of uncertainty about the nature of those benefits. If this is the case in basic science, it is amplified in more applied research, where there is a very high degree of uncertainty about the balance that should be struck between open science and patenting, which would help ensure a return on investment. The move to more openness has been hampered by this lack of evidence.

Academic career paths: Will open science work for university scientists?

Current career paths and researcher evaluation methods do not necessarily encourage open science. Academics often need to point to high impact publications in journals that are not open access. There is mixed evidence about how university scientists experience the push towards open science. This is potentially an important subject for a discussion about how university-industry collaboration might evolve.

Some evidence suggests that open science activities tend to be considered time-consuming, and not necessarily as rewarding career-wise as traditional research. In a 2014 public survey on Science 2.0 (now known as "Open Science"), 88% of respondents cited a perceived lack of credit for researchers involved in open science activities as a barrier to open science itself [European Commission, 2015]. This was the second largest barrier for individual scientists. Other barriers included uncertain benefits for researchers and a lack of financial support for those activities.

Concerns about the effects of open science activities on careers vary depending on the respondent's career stage. A 2014 knowledge exchange report on data sharing found that early career researchers feared getting scooped (having results published by someone else before the researcher has published them) and the potential embarrasment of publishing immature or potentially inaccurate data. Mid-career researchers did not fear embarrassment, but did worry about their research results getting scooped. Further, they hoped to maximize the number of publications they could get from a data source and hence may not have wanted to share it [*van den Eynden, Bishop,* 2014].

Despite these concerns, evidence is growing and it demonstrates that embracing open science practices can improve careers. A recent review highlighted a number of small but potentially important effects on researchers' careers [*McKiernan et al.,* 2016]. These included the fact that open access publications receive more citations and more media attention than closed access papers. Open research practices can help researchers find collaborators and open up possible job and funding opportunities. For example, Publons, a website where researchers can register their peer-reviews including whether or not they were open, produces a report that researchers can put on their CV to display their activity in general and their level of openness.[4] The journal *Psychological Science* has introduced badges attached to papers if the paper provides links to open data or open materials. Early evidence suggests these badges encourage openness [*Kidwell et al.,* 2016].

Is the increasing fragmentation of initiatives a problem?

Policies encouraging open science, and in particular open access, have taken off and multiplied over the last ten years. As of July 2016, ROARMAP,[5] which records open access policies and mandates worldwide, contains 779 policies; 133 of these are funder policies (54 of these funders also carry out their own research), and the other 636 are held by research organizations or sub-units of research organizations. European institutions hold 463 of the 779 policies. These policies vary greatly between and within research organizations and funders, with differences including:

- Whether open access is mandatory or encouraged,
- Priority of green or gold publishing[6], and
- Whether temporary embargos are permitted.

The Pasteur4OA report on open access policies [*Swan et al.,* 2015] highlights the need for aligned policies, noting that researchers may receive funding from more than one funder, and if there is a significant difference between policies, there may be conflicts. Due to the large variety of open access policies and the lack of evidence about what constitutes a good one, there are ongoing efforts to compare policies and develop a measure of the "strength" of a policy [*Vincent-Lamarre et al.,* 2016]. This could then help R&D funders develop more unified and effective policies.

Other aspects of open science policy are currently less developed and appear fragmented. Declarations regulating data sharing are not as numerous as those regulating access to research publications, but they are no less diverse. Funding organizations are not only ones whose policies affect researcher activity. Institutions and publishers also have policies on open access and data sharing. This means that when a researcher wishes to publish an article, they must understand the policies of their funder(s), the institutions and their chosen publishing location, as well as work out how to satisfy all three at the same time.

Do we need new policy tools, including indicators and monitoring tools?

Open science initiatives are in line with many researchers' own beliefs about the importance of knowledge exchange and collaboration. They are being pursued in earnest by the researchers themselves through grassroots-style efforts to build online communities to share information and ideas. At the same time, funders, publishers, industry and citizens are closely engaged in open science activities, driving their development at multiple levels. Recently, the movement has furthermore received serious attention from governments and other institutions worldwide. In the U.S., the White House Office of Science and Technology Policy has developed measures to increase public access to federally-funded research results[7].

The EU has gone even further, making it one of three main priority areas for the European Commission's science, research and innovation policy [*Moedas,* 2015]. The EU and its member states have acted to facilitate open science in some areas, such as open access to research publications, which is required by EU policy. Open data policies and infrastructure development are under discussion. For example, a pilot initiative, Open Research Data, was launched under Horizon 2020. Some of the most relevant issues underpinning open science have been addressed on the European Research Area agenda [European Commission, 2012a] and reflected in European Commission recommendations on access to and protection of scientific data [European Commission, 2012b]. Such measures are designed to improve access to scientific information produced in Europe.

Despite the momentum building around it, the movement toward open science is still in its infancy. Acknowledging this, the European Commission set up the Open Science Platform in 2016, which is composed of representatives from all European states participating in open science initiatives[8].The Platform was designed to provide expert advice to the Commission about how to develop and implement open science policy. It guarantees that any policy initiatives are based on an informed view of the benefits and drawbacks of open science, which increases efficiency and lowers costs.

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[4] https://publons.com/.

[5] https://roarmap.eprints.org/.

[6] Where gold refers to an article being published open access in a journal, and green refers to the article being deposited in an Open Access repository after publication in a subscription journal.

[7] U.S. OSTP (ND) "OSTP Public Access Policy Forum", https://www.whitehouse.gov/administration/eop/ostp/library/publicaccesspolicy.

There is a real need to better understand where open science activities are concentrated: in countries, amongst disciplines and at different stages of the research process. It is still too early to really begin to measure the impact of efforts in this area. As such, there is potential for developing monitoring tools that can help one track trends in open science as an initial step towards informing policy-making in this area. Over time, as the effects of this model begin to be understood, monitoring activity can serve as a foundation for assessments of open science achievements.

The key characteristics of open science, such as free access to scientific publications and databases, must be further studied. In order to meet this challenge, the EU has begun to build an open science monitor, which is developing indicators that can illustrate open science trends at all levels of the research process: from idea generation and funding to data collection, analysis and the publication of research findings [*Smith et al.,* 2017]. Such a monitor can help the European Commission and its advisors better understand how open science is evolving in Europe and in other parts of the world. This will allow them to focus on areas where the most impact can be achieved through policy initiatives.

Policy challenges

Growing support from research funders and policymakers suggest that the momentum behind open science is likely to continue building. This article has outlined mounting evidence that open science presents a convincing alternative to traditional models of scientific activity and the conventional metrics used to define academic success and career progression. We tried to set out some of the key questions and issues underlying the rate and direction of change in open science. In conclusion, we argue that the impact on industry-university collaboration will rest on several key assessments made by stakeholders and policymakers.

First, to date there have been relatively few evaluations of the costs and benefits of open access approaches to publications and data. There have been some assessments of individual schemes such as those carried out by the Structural Genomics Consortium (SGC) and RAND Europe [*Morgan Jones et al.,* 2014]. However, decision making would be facilitated by studies that span initiatives and develop broader frameworks and criteria for evaluation. Many in both the private and public sectors naturally view the move to open data sharing as extremely risky and think that the extent of benefits gained will depend on the particular contexts in which open science approaches are implemented [*Morgan Jones et al.,* 2014]. The rate and direction of moves towards more openness, and the success or failure of the movement as a whole, are likely to be affected by the nature of evidence produced over the coming years. Steps taken by the EU to build a monitoring mechanism are extremely constructive in this respect.

Second, researcher attitudes to open access publishing will to some extent depend on the way that they are assessed. In the UK and other countries, evaluations of the performance of university-based researchers have begun to change [*Manville et al.,* 2015]. The Research Excellence Framework (REF), which for the first time assessed research and allocated funds on the basis of academic and non-academic research, could potentially break down the nexus of factors underpinning academics' overwhelming concern about publishing in high impact journals. If university researchers can point to a variety of indicators to support claims of excellence and impact, the incentive to publish in those journals would be undermined to some extent and make publishing in open access journals more appealing. There is also some evidence that open access journals have more citations than their traditional counterparts, and this may influence university researchers' choices.

The REF is beginning to change the way in which UK universities reward and promote academics [*Stern,* 2016]. Nevertheless, the weight of long-standing traditions of a culture that measured research activity according to quite a narrow set of academic achievements means that the system is unlikely to change smoothly or rapidly.

With regard to the impact on university-industry collaboration, many questions still remain. While the logic behind the potential benefits of open access publishing are clear, there is limited empirical evidence about how it influences companies' absorption of research results. Monitoring and evaluation tools are needed both to clarify the situation as it exists and to provide evidence for better decision making. If this is true for open access, it is even more relevant for open data approaches, which may well have greater implications for patent activity. The extent to which universities support more open approaches will depend in part on how the broader community feels about open access and open data. The pace and direction may well be impacted by the availability of evidence, which can be used to support the move to openness. Steps are being taken to gather evidence about the impact of open access and data repositories, but there are numerous difficulties associated with the exercise and endeavors are still at a relatively early stage [*Keserű,* 2015].

There is still uncertainty regarding the future of non-academic metrics and the role they will play in policy. The UK is committed to the continued use of non-academic metrics and is encouraging the development

[8] http://ec.europa.eu/research/openscience/index.cfm?pg=open-science-policy-platform.

of a broader range of assessment metrics [*Stern,* 2016]. Other European and US institutions are interested in similar policy trajectories [*Guthrie et al.,* 2013]. However, the UK appears to be the frontrunner in introducing a national scheme that bases funding allocations on broader impact metrics, and the extent to which other countries will follow remains unclear.

One of the unintended consequences of the growing enthusiasm for open science is the plethora of initiatives that are being undertaken to promote and support relevant activities. As we have pointed out, initiatives and policies are issued not only by a wide range of different funding bodies but also by some universities and publishers. Whilst this is good news for those supporting open science in some respects, it could be that the fragmentation and confusion surrounding policies undermine long-term development in this area. If the complexity adds to transaction costs, it may even inhibit the development of open science-based partnerships and collaboration. This danger is particularly relevant for partnerships between universities and businesses. Work on the Structural Genomics Consortium indicates [*Morgan Jones et al.,* 2014] that the opportunity to conclude agreements that are as simple and transparent as possible encourages companies to engage in collaboration. However, if various organizations and institutions begin to impose a wide range of different standards, one of the main advantages for partners to engage in collaboration may be nullified. The ability of funders and policymakers to define a coherent and shared agenda is likely to be an increasingly important factor in the way in which open science evolves. Of course, this agenda would ideally be based on an evaluation of the various approaches and the evidence-based development of more standardized approaches. However, political and interest-based considerations may likely play some role in determining the future shape of open science policies. It will be vital for those interested in using open science to structure university-industry collaboration in such a way that it is possible to monitor the developments and support approaches that serve the interests of all parties for sustainable and useful cooperation.

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Service or Devotion? Motivation Patterns of Russian Researchers

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Abstract

Most current studies of highly-skilled personnel argue that intrinsic personal motivation is their critical feature and this motivation has a non-linear connection with external management actions. In order to bring scientists into the sector of research and development, as well as maintain the competitiveness of national science, a special environment must be created, which will encourage a high level of self-motivation among researchers. The analysis of motivation patterns of researchers provided in this paper is based on data from the international project, "Careers of Doctorate Holders" (CDH), and its Russian counterpart, "Monitoring Survey of Highly Qualified R&D Personnel". One of the goals was to investigate the stability and variability of researcher's motivation during the different periods in one's career: choice of profession, current work activity and a hypothetical job change. The eight most common patterns of motivation were identified and they can be considered the basic motivational structures of researchers. The most significant feature of these patterns includes a focus on the creative and innovative nature of scientific work. The second most important component is the independence and relative autonomy, which is typical for research activity. Economic motives are rarely important when choosing an academic career; however, they play an important instrumental role during actual research work, since an appropriate material base is required for the successful achievement of a researcher's professional goals. A hypothetical situation of a job change, including moving abroad (for a long or limited amount of time) also shows the priority of internal personal motives over external ones, which are associated with material conditions.

The opportunity for professional and personal achievements plays the role of a trigger for the high level of motivation of Research and Development (R&D) personnel. The main drivers of research motivation are self-realization, improvement of skills and competences, therefore the professional environment must be organized properly to promote the advancement of intellectual workers. Management based primarily on the external rewards may even reduce personal motivation, since it transforms people's natural enthusiasm and turns their interest solely to material goods. The research results obtained give us reason to argue that the Russian scientific policy agenda must include the creation and maintenance of adequate conditions in which research potential can be fully realized and where the personal reputation of the scientist will be recognized.

Keywords: scientific personnel; doctorate holders; R&D; research motivation; scientific career; science and technology management.

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The most important policy aimed at attracting and retaining R&D personnel would be the creation of a professional environment specifically designed to foster the strong motivation of researchers. Frequently personal motives are more important to scientists involved in promising, cutting-edge research fields than external administrative conditions. Having a better understanding of a researcher's motivation, and how the main driving factors emerge, would be very relevant to the R&D managers, given that it would help them concentrate their efforts and available resources on the factors particularly important to creating favorable conditions for R&D activities and increasing staff productivity.

Optimizing the R&D policies of individual organizations and whole countries, including the development of human capital, becomes increasingly important due to such global challenges as climate change, demographic shifts, and changing value chains. Finding adequate responses to these issues requires international R&D cooperation, and mutual learning within the scope of joint projects [OECD, 2014, p. 138]. Human capital provides "ability, motivation and opportunity to innovate" [OECD, 2015], which makes the efficient management of human resources especially important. This includes promoting interest in a scientific career among young people.

International studies mostly focus not on the concept of researchers' motivation itself, but on analyzing the various mechanisms designed to promote their productivity. This tool-based approach is aimed at improving R&D conditions [OECD, 2014, p. 245] primarily by creating an adequate R&D infrastructure and helping researchers obtain relevant competencies, rather than increasing material incentives for them. Efficient R&D implies the application of various formats for research activities, their flexibility, and a high degree of autonomy for researchers. Material incentives may even undermine team spirit, cooperation, and the free exchange of ideas. Studies also stress the need to develop particular personal characteristics and the need to foster a special "innovation culture", both of which are closely connected with the public's perception of science and technology [OECD, 2014, p. 249]. Young people's declining interest in scientific careers has recently been noted practically all over the world. Targeted government action would help break this trend. Programs to promote building multidisciplinary project management skills also need to be implemented, including intellectual property-related ones [OECD, 2012]. In the absence of such programs, young people find it difficult to adapt to present work environments in the R&D sector, grasp relevant agendas, and fully realize their potential.

The prospects of Russian R&D policy depend not least on how researchers perceive it — i.e., how closely it matches their personal interests and ambitions. The lack of interest (motivation) in enhancing the effectiveness of their activities is one of the most compelling reasons for researchers to leave the R&D sector, and for the overall decline of Russian researchers' performance in 2000–2013 [*Gokhberg L. et al*, 2016]. The importance of assessing the popularity of a scientific career and its social perception determine the practical and theoretical significance of studying researchers' motivations, identifying major incentives, and analyzing motivation patterns, including their sustainability and changes over time.

Main approaches to conceptualizing employee motivation

Despite the large number of employee motivation studies, no generally accepted approach to a theoretical understanding of this phenomenon has emerged in recent years. The existing results represent unconnected theories and concepts that poorly line up with one another, despite the ongoing effort by psychologists and sociologists to integrate them. Still, motivation and its specific aspects, and the incentives relevant in specific occupational environments, remain in the focus of researchers' attention. Such studies are moving towards developing more complex and more closely integrated basic concepts, which can no longer be unequivocally classified as representing content or process, emotional or cognitive theories. Present-day approaches imply building complex integrated models such as, e.g., the meta-theory of motivation [*Ryan*, 2014], while the general trend is moving on from studying specific motives to developing comprehensive theories combining internal and external motivational factors and their temporal dynamics [*Brabander, Martens*, 2014; *Ryan, Deci*, 2000; *Kanfer, Ackerman*, 2000; *Leontiev*, 1996].

The concept proposed by a leading motivation theoretician Alexei Leontiev can be considered a comprehensive or integral one. Leontiev believed that motives were inherently connected with activities [*Leontiev*, 1971]. He stated that a motive is closely linked with the activity's requirements and objectives:

> *"Up to the time of its first satisfaction, the need "does not know" its object; it must still be disclosed. Only as a result of such a disclosure does need acquire its objectivity and the perceived (represented, imagined) object, its arousing and directing activity of function; that is, it becomes a motive".* [*Leontiev*, 1978, p. 161]

Leontiev believed that over the course of an activity motives perform two main functions: the function of supplementary stimulation and the function of sense formation. Motives determine the objectives, in the scope of which a choice of action is made at a later stage.

Regarding work, the "sense-forming function" of motives is stressed, as factors making the work personally meaningful.

Researchers identify three main motives for work: the work's content, earnings, and achieving new qualifications in career development. All of them directly affect each other. For example, earnings can decrease personal motivation, as it reduces enthusiasm and inspiration — inherent human characteristics — to purely material interest. A fruitful approach to studying motivation for knowledge-related, creative work implies not just modeling the overall motivation but conducting a comparative analysis of particular motives that are more important to specific groups of workers. It was already noted that no generally accepted motivation model exists. We should stress the importance of comparing the motives of different groups of workers. In particular, we believe relevant studies should cover the following areas:

- comparing various occupational groups;
- studying the impact of relations at the workplace and management style on the motivation of various groups of workers;
- comparing socio-demographic groups of workers (e.g., comparing the motivations of respondents who belong to different gender, age, education and income groups);
- international comparisons of "nationality-specific" motives identified by various studies [*Konrad*, 2000; *Roe et al.*, 2000; *Silverthorne*, 1992]. For example, employees at the same organization who come from different countries may have very different motives for work. Specific sets of factors motivating particular groups of workers from countries with different cultures or economic development levels (such as migrants or expats) can be identified;
- ranking workers' motives by importance during different periods of their lives, and at different career stages. For example, panel and longitudinal studies are based on a hypothesis about researchers' motives being connected with their employment history, current position, and the financial situation (their own, their organization's situation, and the finances in the country generally). Accordingly, subsequent studies could track the temporal dynamics of motivation.

Most of the studies of work and employment in the R&D sector note the nonlinear dependence of researchers' personal motives on the impact of external administrative factors. Researchers frequently need not so much to be managed as to be able to work in an atmosphere of productive cooperation, freely exchanging knowledge and ideas. Autonomy becomes a key element of researchers' motivation — not management style or specific instructions from the boss, but involvement, and the importance of the problems researchers are trying to solve. Total involvement is the norm for the research community [*Trevelyan*, 2001], along with loyalty to one's organization and colleagues [*Chughtai, Buckley*, 2013].

As R&D management studies emphasize, researchers' motivation is similar to that of knowledge workers (those involved in the creation and application of new knowledge). Recognition, self-realization, and personal freedom have paramount importance to them all — and therefore the work environment must make effective use of this resource [*Dushina, Lomovitskaya*, 2016]. Professional and personal development prospects provide the highest motivation for knowledge workers [*Tampoe*, 1993]. According to various studies, the freedom to manage their workload, work conditions, type of employment, and the team they are members of are the main motives for creative workers [*Todericiu et al.*, 2013].

The effectiveness of tools for increasing researchers' motivation can be estimated by comparing the most popular administrative measures with researchers' opinions about their worth. The authors of a survey of the faculty of Polish and Slovak universities conducted in 2015 [*Blaskova et al.*, 2015] note that managers usually tend to give teachers more autonomy, creating a degree of freedom for them. University teachers believe this incentive to be the most effective one, together with "steps to promote personal development and training…, establish good relations and a favorable atmosphere". At the opposite end of the spectrum are "threats and sanctions". The results of this and other studies indicate that university staff expect management to create an atmosphere of support, i.e., a corporate culture based on mutual trust and respect between management and its subordinates. Another principle favored by the respondents is concentrating on objectives that require the staff to work together to accomplish shared goals, and the promotion of such a joint approach. On the contrary, the current situation is dominated by a corporate subordination culture based on motivating staff by giving them access to resources: people in positions of authority control others by either granting or denying access to various benefits.

Knowledge workers usually do not accept the command-and-control management model [*Drucker*, 1988]. In turn, managers cannot control the process of knowledge creation, which is predominantly latent and irregular (the times of highest productivity can occur outside of office hours). Given all that, researchers may view attempts to introduce stricter controls as a lack of trust, which would lead to reduced motivation. An authoritarian style can be efficiently applied to manage researchers only when a clearly formulated objective must be accomplished rapidly. Under normal conditions of a research team's work, or at the exploratory stage, a democratic or liberal management style would be in place: less directive, giving researchers a high degree of autonomy [*Volodarskaya, Lebedev*, 2001].

Knowledge creation can be described using the 3S concept: self-management, self-organization, self-control [*Mládková*, 2015]. Researchers can efficiently develop ideas suggested by others only if it matches their own research interests and ambitions. Participants in joint projects are frequently motivated by personal enthusiasm, not by orders or instructions from above. Team projects provide an opportunity to participate in something big and important, and to more fully realize one's personal potential. These individual agents' motivation to cooperate and take part in joint activities ultimately contributes to the overall success of the whole undertaking [*Lotrecchiano et al.*, 2016].

Different motivation patterns can play different roles, depending on the prevailing socioeconomic situation in the country. Personal motivation is important to knowledge workers under any circumstances, but if their basic needs are not met, material incentives come to the forefront, as was confirmed, e.g., by the results of Romanian [*Cucu-Ciuhan, Guita-Alexandru*, 2014] and Slovenian studies [*Konrad*, 2000]. The authors analyzed the increasing role of material incentives during periods of economic crisis and recession. Similar trends were observed in Russia in the 1990s, when material straits reached a critical level and many researchers left the R&D sector altogether to earn a living elsewhere [*Kitova et al.*, 1995; *Gokhberg et al.*, 2011]. Asked about their reasons, researchers noted low pay, uncertain prospects of their R&D organizations, and the declining social status of scientists [*TSISN*, 1993]. Of course, during hard times, when researchers' basic needs remain unmet, it would be unrealistic to expect that their personal professional interests alone would be enough to carry on in academia. Note that not just outflow of research personnel is critically important; equally crucial is the reduced inflow of young graduates into the R&D sector, which "leads to changing priorities and values when the most gifted young people make their career choice" [*Gokhberg et al.*, 1999].

The key factors affecting the choice of a scientific career must be taken into account when national and international Science and Technology (S&T) policies are shaped. Many countries would like to attract highly skilled professionals to the R&D sector, and are trying to create favorable conditions for them. The most complete and structured data about the motives for choosing a career in science, researchers' employment, and specialization areas were collected within the large-scale international project Careers of Doctorate Holders (CDH), which covers 25 countries (including Russia) and is being implemented under the auspices of the OECD, the UNESCO Institute of Statistics, and Eurostat. Similar surveys conducted previously [*Auriol*, 2007, 2010; *Auriol et al.,* 2013; *Gokhberg et al.*, 2016] revealed that researchers in all countries are primarily attracted by career opportunities and the nature of the intellectual challenges they would have to meet and overcome, followed by the degree of autonomy and the level of responsibility they would have in such positions. For example, about half of the respondents (51.4%) in Belgium chose academic careers due to their interest in science; other motives included creative and innovative work, independence, and an opportunity to contribute to the broader development of society [*Boosten et al.*, 2014]. In the majority of participating countries, the least important motives for researchers included earnings and benefits; note that the correlations between them and the degree of researchers' satisfaction was nonlinear and unclear.

An analysis of the results of the project, "Monitoring Survey of Highly Qualified R&D Personnel" [*Katchanov, Shmatko*, 2011; *Shmatko*, 2011; *Shmatko, Katchanov*, 2016], which was implemented in the framework of the Russian part of the CDH survey, reveals similarities and differences in the motivations and work conditions of Russian researchers compared with relevant global trends.

Methodology of the study of Russian researchers' motivations

The main objectives of the study included identifying Russian scientists' (doctorate holders) motivation for choosing a career in the R&D sector, and the main reasons of their continuing interest in research work. Our analysis was based on Alexei Leontiev's concept; our starting point was researchers' self-assessment of their motives, and the goals and objectives they expected to accomplish at work. Taking into account the fact that specific motives' importance changes at different stages of a researcher's career, particular attention was paid to three key stages: (1) choosing a career in science, (2) working in the R&D sector, and (3) the probability of a career change.

Data about Russian doctorate holders was collected through a sampled survey using a multistage stratified sample, with respondent quotas established for age groups, gender, specialization areas, employment sectors, and territories of residence (federal districts). The total sample comprised 2,830 doctorate holders representing natural and engineering sciences with the highest potential in Russia, namely physics, chemistry, material science, nanotechnology, information technology, energy, mechanical engineering, mechanics, and biology. 53.5% of the respondents were employed by research institutes, and 46.5% — by universities. The collected data allows one to compare the motivations and values of researchers representing various knowledge areas and those with different socio-demographic characteristics, and to identify correlations between their specific motives and career paths.

Regarding the *career choice stage*, researchers were asked to specify the main reasons for their choosing a career in science and education over other occupational options. Regarding the *working in the R&D sector stage*, the respondents could specify the most important opportunities offered by their chosen field, and specific individual needs their academic career allowed them to meet. To assess the *probability of a job or career change*, the respondents were asked about their willingness or intention to find a different job, and if so, which one they would prefer. They were also asked if they had any plans to leave Russia within the next 12 months to work abroad, and if yes, what were the reasons for doing so. To find out what limitations researchers would be willing to accept for the sake of having an interesting job, they were asked about potentially unfavorable conditions that they are ready to accept for participation in a project of national importance.

Motivational structure and key factors affecting the choice of a career in science

Chosen professional activities reflect people's values and interests. Meeting their career goals and obtaining "tangible or intangible, perceived through the senses or purely imagined" results actually constitutes motivation [*Leontiev*, 1971]. Doctorate holders specializing in natural and engineering sciences participating in the survey were asked to identify what they consider the most important interests they were trying to realize by making their career choice. The results are presented in Figure 1.

We can see that the need for knowledge and creativity plays a key role in choosing science and education as the areas for one's professional self-realization: "creative and innovative work" and "personal research interests" were among the researchers' main motives, and these certainly belong in the personal motives category. External material incentives such as "well-paid job" and "bonuses and benefits" turned out to be at the bottom of the list of priorities, which is fully in line with the results of international studies [*Ryan*, 2014; *Lam*, 2011; *Cucu-Ciuhan, Guita-Alexandru*, 2014], previously collected Russian data [*Gokhberg et al.*, 2016], and data for other countries participating in the CDH survey. For example, in Belgium and Spain, the respondents also named "creative and innovative work" as the main reason of their choosing a career in science — more than 60% and 70%, respectively. The second most important motive — personal research interests — was noted by 54.9% of Russian, 51.4% of Belgian, and 67.7% of Spanish researchers.

Personal motives obviously prevail when choosing a career in science, regardless of the respondents' country of residence. Certain differences were discovered between Russian and European scientists' social motivation: there were fewer altruists among Russian researchers at the career choice stage: the "serving society" motive was the third most important to Spaniards (47.3%) and the fourth most important to Belgians (32%), while in Russia it was important only to 14% of respondents. At the same time, Russians valued independence in choosing their research objectives and finding ways to accomplish them no less important than Europeans did. In all countries, material motives were at the bottom of the list of reasons for choosing science as a path for self-realization; however, if in Belgium about 10% of the respondents chose an academic career because it is well-paid, in Russia and Spain the relevant share was no more than 5%.

An analysis of the questions that allowed one to give multiple answers enables us to consider distributions not only of specific variables, but also of their combinations, i.e., the combinations of several motives. This is important since only 11.1% of the respondents gave just one answer, while 16.2% indicated two motives, and 72.7% - three.

Regarding researchers who only gave one motive for choosing a career in science out of the available options, it can be concluded that it was exceptionally important to them compared with the others. Not a single one of the surveyed doctorate holders indicated factors such as "well-paid job" or "bonuses and benefits" as their only motive, which again confirms the premise concerning the secondary role material incentives play for scientists. From the very start of the "Monitoring Survey of Highly Qualified R&D Personnel" project in 2010 [*Shmatko*, 2011], monetary considerations were never at the forefront, and only supplemented personal and social motives for choosing a career in science. The relatively low income usually earned in this highly skilled professional area does not foster such expectations among people who are thinking about an academic career.

Intellectual self-realization and personal and social achievements are the main motives for research work. So, the share of respondents who named "creative and innovative work" as their main and sole motive was over half of the total (50.2%). Among other motives indicated as the only ones, "it was the only

Figure 1. **Relative weights of motives the respondents named as the main ones in their career choice (%)**

Source: composed by the authors based on the survey data.

available choice" or "I had to go for it" stand out — this happened when people became researchers because they were offered the position after graduation, or "other employment was not available". In total, 9% of the respondents indicated these options. Only 5% of those surveyed who named a single motive for becoming a researcher were hoping for professional development and career growth.

The answers of the respondents who provided the most detailed information about their motives for choosing a career in science (those who selected three motives out of the possible three) can be seen as basic motivation patterns typical to researchers' personalities. Most of these "motivation triads" (88.2%) included "creative and innovative work" as the top motive for choosing to work in academia. Other popular motives were "independence", "personal research interests", "ambition to develop an academic career", "comfortable working conditions", and "serving society." Such factors combine personal and social dimensions. Material incentives were conspicuously absent as a significant factor here too, either directly or in combination with other motives.

The composition of the motive triads allows one to speak about motivational patterns, and the corresponding types of researchers specializing in natural and engineering sciences. We identified eight such types (Figure 2).

Four out of the eight above motivational types can be considered the most common, and the four others are secondary, representing smaller subgroups of researchers.

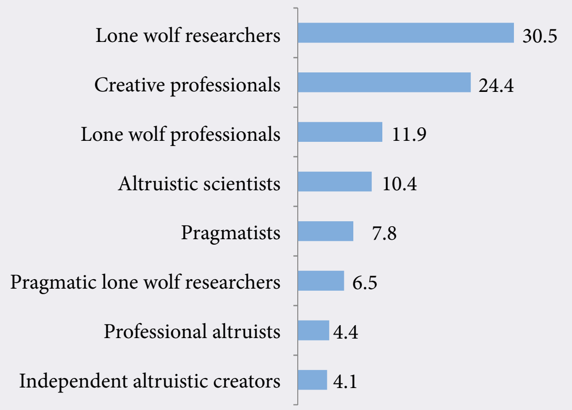
The *first* motivational pattern is typical for the "*lone wolf researchers*" group. It comprises motives such as "creative and innovative work", "personal research interests" and "independence", and was particularly common among the respondents. The *second* motivational pattern corresponds to the "*creative professional*" type, and combines the "creative and innovative work", "professional development and career growth", and "personal research interests" motives. Researchers in this group (25% the sample) were primarily motivated by personal development and career growth opportunities when they chose their profession. The *third* type, "*lone wolf professionals*", are researchers who were motivated by the creative and innovative nature of research work and strived for independence and professional development (about 12% of respondents). The *fourth* motivational pattern is typical to "*altruistic scientists*" who were also driven by the creative and innovative nature of the work combined with the willingness to serve society at large and their own personal research interests. This motivational type — researchers for whom serving society is important — is much less frequent: only one in ten respondents belong to this group.

The four secondary motivational patterns and corresponding researcher types include the following main motives:

- *pragmatists*: creative and innovative work, focus on comfortable work conditions and personal research interests;
- *pragmatic lone wolf researchers*: creative and innovative work, focus on comfortable work conditions and independence;
- *professional altruists*: creative and innovative work, a desire to serve society, a focus on professional development and career growth;
- *independent altruistic creators*: creative and innovative work, aspirations for independence, and a desire to serve society.

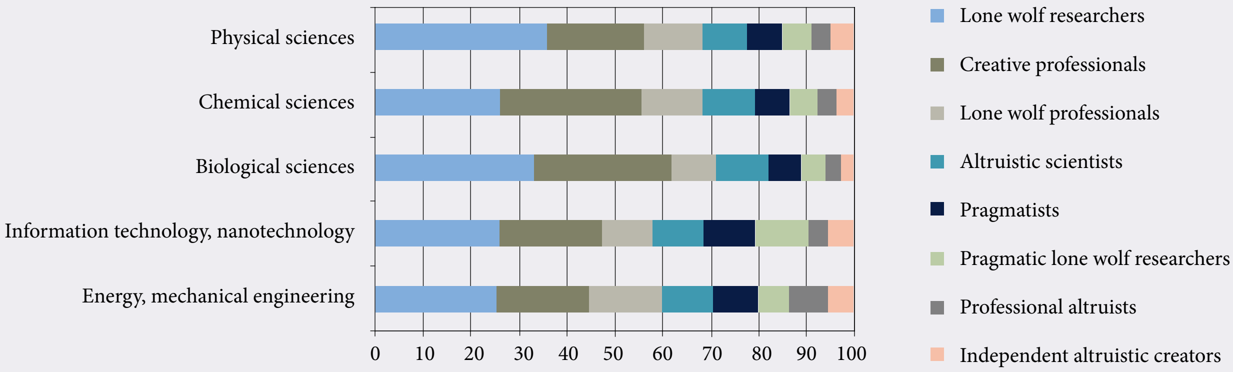
The above types are not equally distributed between the various fields of the natural and engineering sciences. *Lone wolf professionals* are most commonly encountered among physicists and biologists, and much less frequently — among chemists and energy engineers; on the other hand, *creative professionals* usually specialize in chemistry (Figure 3).

Figure 2. **Types of doctorate holders specialising in natural and engineering sciences, based on their professional motivation patterns (%)**



Source: composed by the authors based on the survey data.

Figure 3. **Distribution of motivational types by research fields (%)**



Source: composed by the authors based on the survey data.

We compared the small group of doctorate holders who named "well-paid job" and "bonuses and benefits" as their main career choice motives with those for whom earnings did not particularly matter. Researchers with pronounced material motivation more often happen to be men, and generally they are younger than their colleagues who are not interested in financial incentives: the average age of the first group is 47.5, and the second — 56. Note that researchers who held senior positions during the survey were no more interested in material incentives at the time of their career choice than the rank-and-file scientists were. On the contrary, the share of those who have stated they were mainly motivated by creative and innovative work among today's managers was even slightly higher. Doctorate holders primarily interested in meeting their material needs were more frequently employed by universities than by research institutes, and had more than one job: about 58% of them had two or more employers, while the relevant figure for those who had not been motivated by material incentives was 44%.

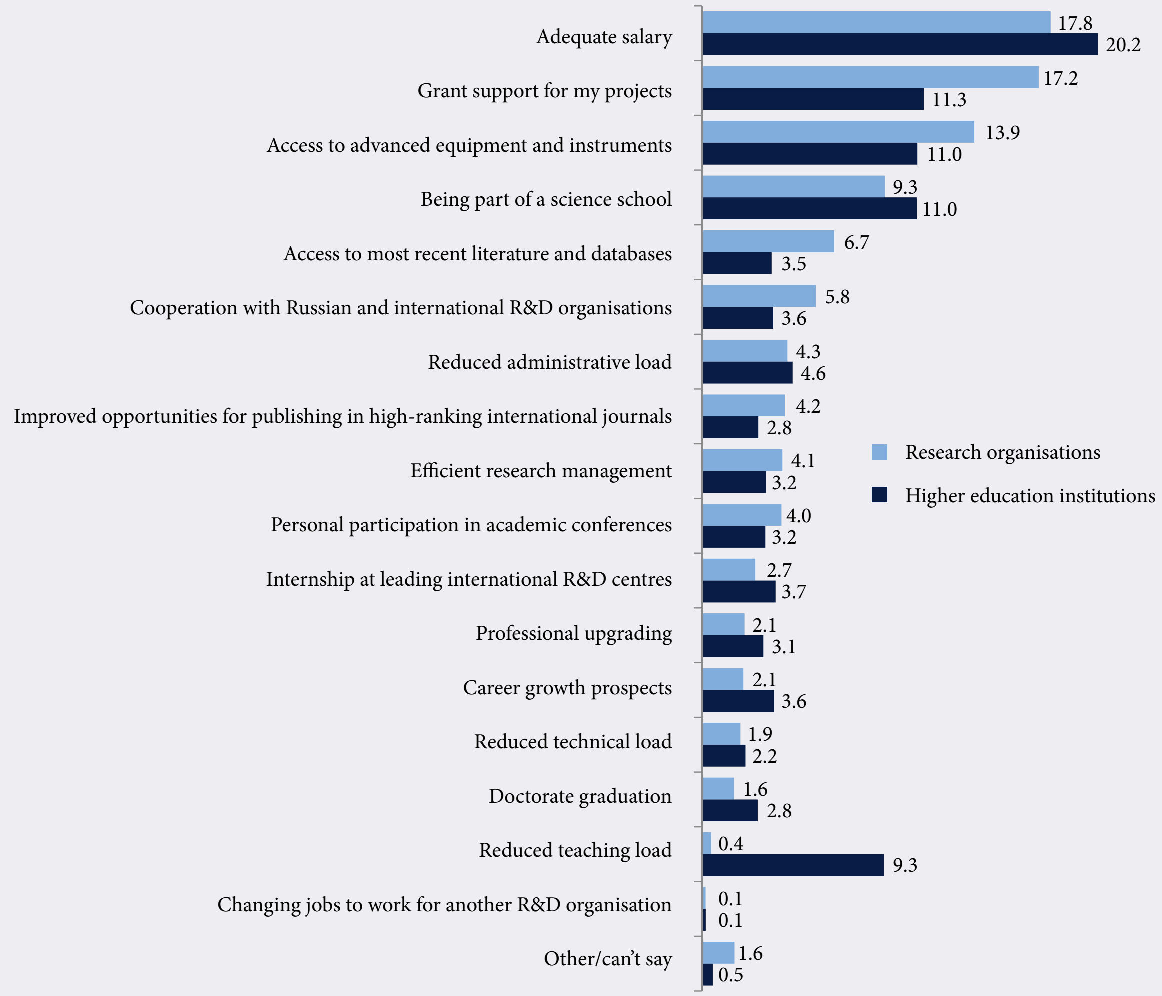
Next, we considered the small group of researchers who did not indicate either "creative and innovative work" or "personal research interests" as their reasons for choosing a career in science. As the survey showed, members of this group work at universities much more often than the average for the whole sample, while their main motives were comfortable working conditions (18.9%), professional development prospects (15.5%), independence (14.1%), and social security (11.5%). All surveyed doctorate holders noted independence as a decisive factor in their career choice, which allows to one cite the relative autonomy guaranteed by research work as the second most important motive for choosing a career in science. We stress that our ranking of motives did not take into account whether a job in the R&D or education sectors was the only one the respondents had or whether they also held other positions; their average monthly earnings were not considered either.

Sustainability and variation of researchers' main motives

Researchers may have different priorities at different career stages, affecting their work-related objectives. Motives that were relevant during the earlier stages of their career may not be the same that drive their current activities. This gap is most evident in the material aspects of researchers' work. At the same time, the higher relative importance of material needs does not necessarily confirm the popular theory by Abraham Maslow, according to which intangible motives become more important as people's basic needs are met [*Maslow*, 1970]. One of the specific features of research work (as well as of any other autonomous social area) is that competing for academic recognition, administrative and financial resources, and also specialization or cooperation, affect researchers' practices and perceptions. Frequently, success in this field does not depend on material factors, and the correlation between salary and productivity is far from being linear. Material factors, which seem to be secondary at the career choice stage, may become much more important later on, when researchers have to deal with specific R&D problems. The subjective perception of various factors by the respondents, which affect their ability to accomplish specific professional objectives, is illustrated in the diagram below (Figure 4).

The results of our survey allow us to conclude that Russian doctorate holders see material aspects of their work not as something worthwhile in itself, but rather as a means to accomplish important research objectives. In Frederick Herzberg's words [*Herzberg*, 1964], the financial aspects of researchers' work can be seen as "hygienic factors". They do not increase motivation by themselves, but their lack may lead to dissatisfaction because a high salary would make finding additional work unnecessary, and access to sufficient research funding (including grants) allow researchers to concentrate on their main functions in their pursuit of self-realization and new discoveries. However, a more common situation is the gap between researchers' needs and the actual opportunities made available to them.

Figure 4. **Factors affecting Russian doctorate holders' perception of professional success (%)**



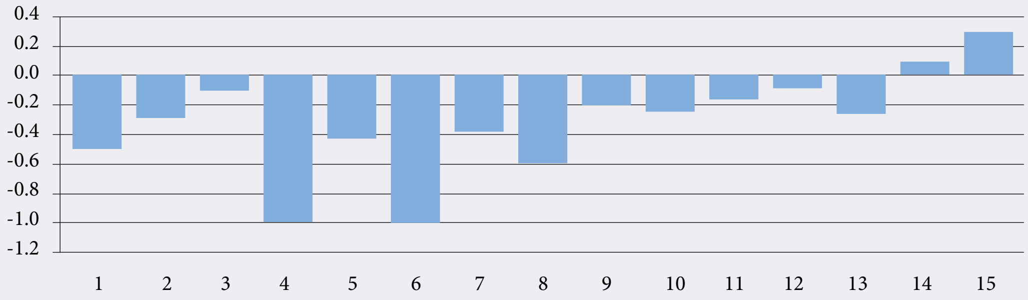
Source: composed by the authors based on the survey data.

Doctorate holders were asked to evaluate various opportunities present at their workplace, and to what extent they were actually able to make use of them. This allowed the authors to determine exactly where the gap was widest between the opportunities that were actually available and hypothetical opportunities. The resulting list includes personal, social, and material motives whose balance (the difference between averaged-out estimates of the extent to which the researchers' work allowed for exploiting these opportunities, and how important they were to them, on a scale of one to four) is presented in Figure 5. Negative figures mean that the actual realization of the relevant motives at the current place of work was lower than their perceived importance to the respondents; positive figures imply that the relevant opportunities were implemented beyond the respondents' expectations. The widest gap was observed between material ("decent income", "adequate material situation") and personal aspects ("feeling of stability", "confidently looking into the future"); it seems that research work does not allow one to fully meet such needs. Only in two cases did current work offer an excess of potential: opportunities for making extra income both in the R&D sector and outside it. The practical realization of all other opportunities remains problematic.

According to the data collected for the Russian segment of the CDH survey, in Russia, the share of researchers who are rather dissatisfied or completely dissatisfied with their earnings is the highest among all participating countries, at 59.3%; the same applies to benefits provided to researchers (64.8%). Note that among all the countries participating in the project, Russia had the lowest median gross annual income (in purchasing power parity terms, in rubles, by the end of 2009). On average for all surveyed countries, R&D personnel were least satisfied with their earnings and work-related benefits [*Auriol*, 2010; *Auriol et al.*, 2013; *Gokhberg et al.*, 2016], regardless of whether they were engaged in R&D as researchers or not.

Doctorate holders in other countries, especially those employed outside of the R&D sector, also were not always happy about their career opportunities — not by far, and least of all in Portugal, Belgium, Turkey, and Spain (more than 40% of the negative responses); in Russia, their share was much more modest, at

Figure 5. **Difference between averaged-out estimates of how far various opportunities were implemented, and their perceived importance to Russian doctorate holders**



Opportunities offered by research work

1 – Professional self-realisation
2 – Manage one's own workload
3 – Live one's life in line with one's interests apart from work
4 – Have a decent income
5 – Contribute to development of one's research field
6 – Have a feeling of stability
7 – Develop one's own ideas for the sake of learning and discovering truth
8 – Practically implement one's ideas
9 – Work together with likely-minded people
10 – Serve the society
11 – Achieve public recognition
12 – Have an interesting circle of social contacts
13 – Participate in international research projects
14 – Have opportunities to make additional income by doing research work
15 – Have opportunities to make additional income by doing work unrelated to research

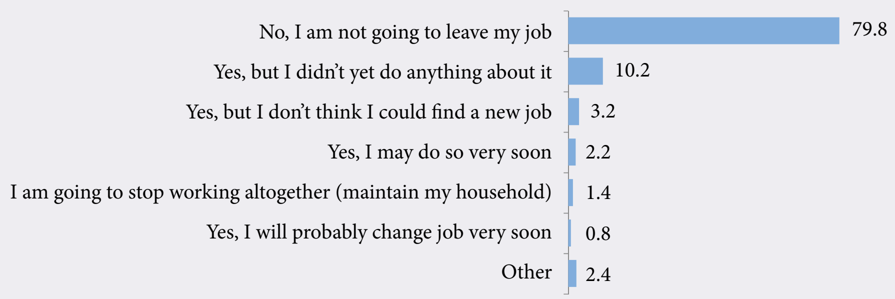
Source: composed by the authors based on the survey data.

23.4%; i.e., more than three quarters of Russian doctorate holders were happy or rather happy about their opportunities for professional development. However, regarding specific aspects, such as independence, scope for accomplishing knowledge-related objectives, and working conditions, Russian researchers' dissatisfaction was much higher than that of their colleagues in other countries.

Dissatisfaction with material aspects does not automatically lead to a mass exodus from academia, since this is the only environment where a significant portion of researchers' specific needs can be met at all, and those needs are more important to those researchers. Almost 80% of the respondents noted that they did not plan, and would not like to change their job, and those who were thinking about it had not yet taken any practical steps. Only 3% of the respondents declared such an intent, or the high probability of finding a new job in the near future (Figure 6).

Even researchers in the lowest income group do not often think about changing jobs, or even the area of their professional activities. The share of those who did think about finding a new job but have not yet taken any practical steps is slightly higher in this group than the average for the sample (13.8% and 10.2%, respectively). However, the share of those planning to change jobs in the near future (3.4%) is only slightly higher than the average for the sample (3%). Note that more than half of the doctorate holders who did consider this option do intend to stay in the R&D and educational sector, and only about a quarter of them would like to leave academia. Less than one percent of the sample were thinking about leaving the R&D and education sector in the near future.

Figure 6. **Distribution of Russian doctorate holders' answers to the question "Would you like (are you going) to change job?" (%)**



Source: composed by the authors based on the survey data.

Figure 7. **Distribution of Russian doctorate holders' reasons to leave the country to work abroad (%)**

Source: composed by the authors based on the survey data.

Among the reasons prompting researchers to leave Russia, temporarily or permanently, personal and material motives remain at the forefront (Figure 7). A fifth of doctorate holders (20.4%) who plan to leave Russia in the next year noted "unsatisfactory funding of research and corruption in grant allocation". In this case, the motives for leaving the country cannot be classified as predominantly material; rather, researchers see the material aspect as a barrier hindering their professional self-realization, getting in the way of thoroughly studying the subjects in which they are interested. It is the barriers hindering their productivity, such as unfavorable conditions for research, limited access to advanced equipment and materials that they need for their research, poor opportunities for cooperation, for establishing their own research teams or new research areas that prompt researchers to change the country of their work and residence.

We can see that material motives are not only the most unimportant reasons for researchers' choice of career, but having those motives not be met does not even constitute the main reason for their leaving academia, though it does hinder researchers' professional development. This is yet another confirmation that personal and social motivations are far superior to external material factors — a typical characteristic of science as an autonomous, social field.

Understanding Russian scientists' motivations requires the identification not only of work-related aspects that they find important and the opportunities made available to them, but also the potential inconveniences they are willing to endure for the sake of professional self-realization. During the monitoring survey, researchers were asked the following question: "If you were invited to take part in an advanced project that was strategically important for the country or the world as a whole, would you agree to do so under the following conditions?" The distribution of the answers is shown in Table 1.

Almost three quarters of the respondents were willing to accept a higher workload, work in the evenings and on weekends to be able to take part in an interesting and important project. The share of those willing to accept a lower salary was much smaller. No differences were found between these two groups' personal motivations regarding their willingness to sacrifice income for the sake of taking part in an advanced strategic project, but there were certain differences in their social motivations. Typologically, these researchers belong to the "altruistic scientists" or "independent altruistic creators" groups: at the career choice stage, serving society was much more important to them than to those who were not willing to accept a lower salary (9% and 4%, respectively). Researchers not ready to sacrifice their income for the sake of interesting work were more interested in personal success, professional development, and career growth than their altruistic colleagues. The most common motivational types among them were "lone wolf professionals" and "creative professionals".

Correlation between researchers' motivations and their positions on the labor market

Regarding the question about the conditions of productive work, differences were identified between researchers firmly established on the academic labor market and younger people at the early stages of their career. To researchers who have not yet reached middle age (those under 50 years old), internships at leading international R&D centers and universities were very important, as well as opportunities for professional improvement and the acquisition of new skills. To the youngest respondents, career prospects

Table 1. **Willingness of Russian doctorate holders to accept potentially unfavourable conditions for the sake of participating in an advanced strategic project (%)**	
Condition	**Share of respondents willing to accept**
Will need to change job	59.0
Will need to change place of residence, move to another city	39.6
Will have to work in the evening and on weekends	74.7
Participating will limit freedom of international travel	42.9
Salary will be lower than the current one	11.3

Source: composed by the authors.

were more important than for the whole sample on average, while working on a team of like-minded people was less significant. Older researchers (50+) more often noted "the opportunity to take part in academic conferences and workshops" as a condition of their creative self-realization. These results are fully in line with the conclusions of similar international studies [*Ryan*, 2014; *Cucu-Ciuhan*, *Guita-Alexandru*, 2014]: differences in the motivations of researchers in different age groups are mostly social. Young researchers are interested in advancing their career, tend to be individualistic, strive to make a name for themselves and win recognition without associating themselves with any group. The best opportunities for that are provided by improving one's competencies through courses and internships. Their older colleagues are less concerned with building a reputation in the academic community: frequently they already have sufficient recognition, so the need to voice their opinions and share experiences at various conferences and seminars come to the forefront.

An analysis of the perceived importance of various aspects of research work by members of different age groups yielded similar results. The youngest respondents (up to 29 years old) stated they did not need to work jointly with like-minded people, belong to an existing school of science, or establish one of their own more frequently than the average member of the sample did. Researchers older than 50 were more restrained concerning international cooperation (business trips to foreign countries, internships, etc.), the freedom to manage their time and workload, the realization of their ideas, and getting extra (part-time) work outside academia. At the same time, the basic conditions for self-realization were the same for all age groups: adequate salary, adequate funding of research projects, and access to advanced equipment and materials. Material resources play an instrumental role at all stages of researchers' careers, and are seen by them as an important prerequisites for accomplishing research objectives [*Gokhberg et al.*, 2010].

The educational sphere faces a number of specific issues, which can negatively affect motivation. According to the respondents, working for a university does not allow them to fully realize their professional potential (18.4% of faculty members noted that their "current job completely or partially hinders this opportunity", while the relevant figure for research institutes' personnel was 9.9%), manage their time and workload as they see fit (24.3% and 12.6%, respectively), and realize their ideas (26.1% and 15.6%). Meanwhile, the staff of these two kinds of organizations have the same main problems: insufficient material support and difficulties with the practical realization of their ideas. Research institutes offer better opportunities for international S&T cooperation, and their staff more often than their university colleagues are willing to leave Russia to work abroad for up to one year (7.6% and 4.5%, respectively). However, the willingness to leave the country for a longer period remains at a comparable low level in both of these groups, at about 8%.

Conclusion

This study identified a number of researchers' specific needs that could be met only in the process of research work. Economic and career limitations notwithstanding, researchers tend not to be inclined to change their occupation, which is confirmed by country-specific surveys and the CDH survey's overall results. In Russia, doctorate holders' occupational mobility remains quite low: 80% of those surveyed were not planning to change their jobs, and more than a half of those who considered this possibility were going to keep working in the same field.

Work-related motivation remains the main driver of a researcher's career. A specific feature of the R&D and educational sectors is the innovative and creative nature of the work, which attracts people with a high level of personal motivation. Motives related to the nature of work and personal research interests are at the core of researchers' professional identities. At the micro-level, motivation affects individual researchers' entry onto the academic labor market and their subsequent promotion. At the macro-level, it ensures the reproduction of a pool of professionals. An analysis of researchers' motivations requires the consideration of the context of their work, especially academia's specific features as a social environment with its own very particular laws [*Bourdieu*, 1976]. Successful researchers' activities are aimed at achieving and increasing peer recognition and self-realization, while their incentives remain predominantly intangible. Researchers' motives are derived from the social relationships they participate in during their professional activities. A distinctive feature of more common researcher motives is their autonomy: they are focused on their research. At the micro-level, this quality allows them to integrate into an academic environment, with its (relative) autonomy from other fields — such as economy, politics, etc. At the macro-level, autonomy is a condition that is needed to serve the whole research environment's reproduction.

Researchers' involvement in their work is primarily determined by their interest in achieving impressive results. Material aspects such as earnings and research funding are not very important to researchers as such, but are rather seen as the resources required to accomplish high-priority personal objectives. As personal and social motives are realized, the probability of leaving R&D and educational sectors practically vanishes, even under unfavorable material circumstances, since only a narrow range of occupations fall in line with the specific motives of R&D and educational professionals.

Until recently, an economics-based approach provided the most common framework for studying the motivation of Russian researchers, which implied viewing them exclusively as a *homo economicus*. According to this model, the only way to increase researchers' productivity was by monetary payments. All non-financial mechanisms and aspects of research activities were almost totally excluded from the S&T policy toolset. However, our study suggests that issues related to researchers' professional self-realization and building and maintaining researchers' personal reputations should be put back onto the Russian S&T policy agenda.

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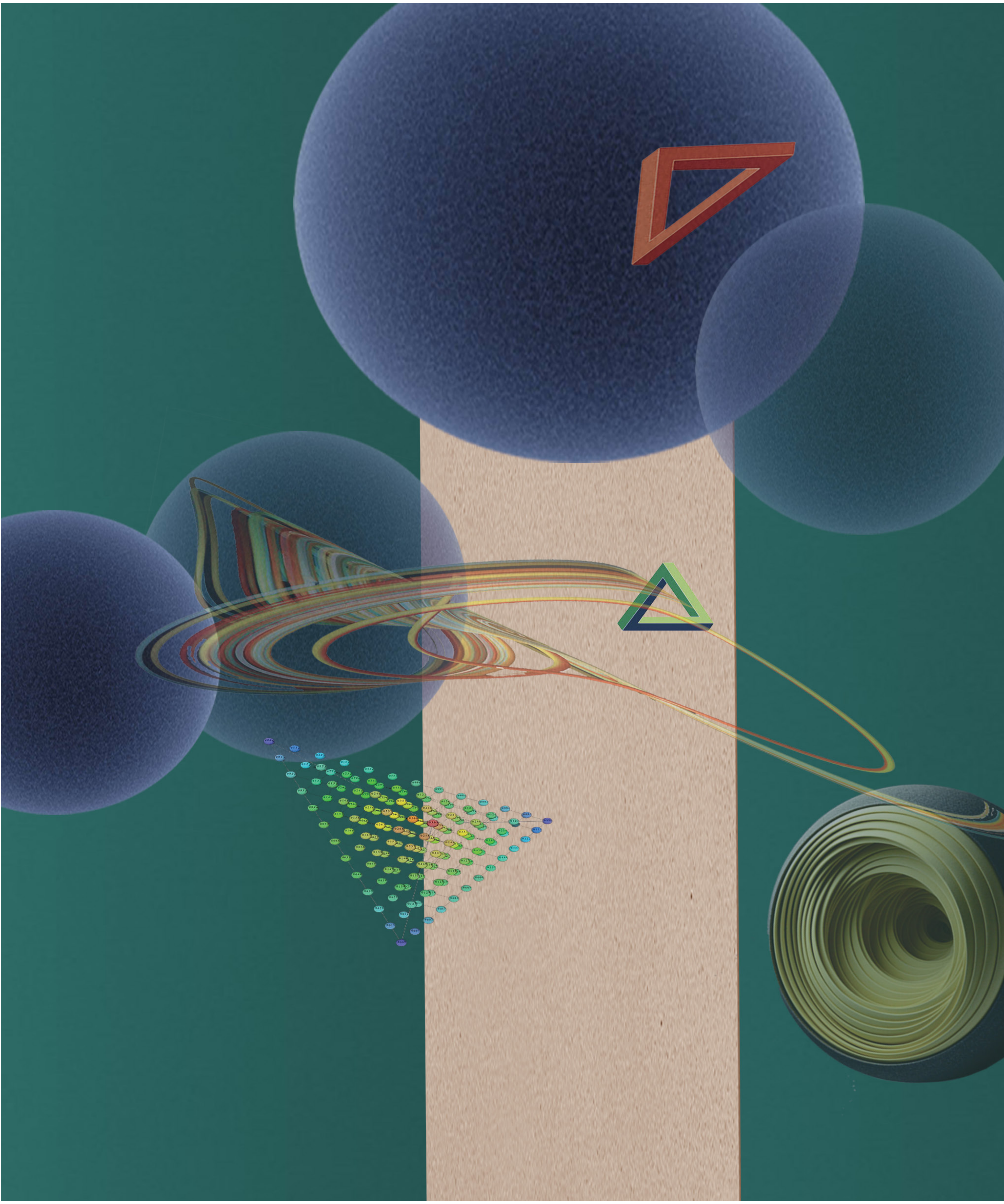

Knowledge Triangle Configurations at Three Swedish Universities

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Abstract

The concept of a knowledge triangle, i.e., the principle of strengthening the linkages between research, education and innovation, has emerged as a result of policymakers' expectations that universities assume a broader societal responsibility. Yet, little is known about how these tasks and their interactions are orchestrated at universities. We explore concept of how the knowledge triangle is manifested in the organisation and strategy of three different Swedish universities, and how these manifestations are shaped by the policy landscape. The article highlights the fact that although the knowledge triangle remains a priority, explicit national policies are lacking, with the responsibility of integration falling upon universities themselves. We observe great diversity in how the principles of the knowledge triangle are orchestrated at the universities, e.g., through individuals' interpretations and attitudes, and through management strategies and incentive schemes. However, the three tasks have largely been handled separately, with weak coordination and generally limited ambition demonstrated by university management teams to forge new combinations of remits. At the individual and group levels, we observe weak task articulation, although some role models serve as inspiration. Tensions emerge as the responsibilities of operationalising the knowledge triangle falls on individuals who sometimes lack the appropriate mandate and resources. These findings raise questions for further research and implications for policy and university management.

Keywords:
knowledge triangle;
university management;
third mission;
societal collaboration;
research utilisation.

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Universities are currently facing mounting policy expectations to assume broader social responsibility. As part of these expectations, policy institutions such as the European Commission and the Organisation for Economic Co-operation and Development (OECD) [European Commission, 2005; OECD, 2016a] have stressed the need to strengthen bilateral and trilateral ties between research, educational and innovation activity[1], which they refer to as the Knowledge Triangle (KT).

Although the value of linking research, education and innovation is well known, strengthening these ties has often proven challenging [*Maassen, Stensaker,* 2011; *Sjoer et al.,* 2016], revealing tensions between the different tasks and institutional levels [*Pinheiro et al.,* 2014]. These tensions are to some extent inevitable, as the logic behind, and the incentive systems of, universities' tasks differ: education is place-bound and localised in its practices and reward systems; research is primarily valued according to its contributions to the international community, whereas innovation takes many different forms, from the tangible to the tacit.

Hence, the task of aligning the tasks and creating meaningful and rewarding ties between them is fraught with tension. Moreover, these difficulties can be assumed to play out differently at different types of universities. Universities are conditioned by factors such as their history, societal connectivity, operational focus and size [*Clark,* 1998; *Stensaker, Benner,* 2013]. This means their strategies and procedures for creating KT links can be expected to vary: teaching-intensive universities start out from their educational mission and align research and collaboration to that mission ("vocational drift"); research-intensive universities can be expected to use education and research as prolongations of their research strengths ("research drift"), whereas universities with strong social connections will mobilize their research and educational tasks to meet the specific needs and demands of their societal environment ("societal drift") [*Martin, Etzkowitz,* 2000]. These developmental paths can then be related to and compared with the ideals behind the KT, namely that that the three missions and tasks develop in parallel and without a hegemonic centre [*Etzkowitz, Leydesdorff,* 2000]. Given the significant policy interest in the KT, we see a need for a comprehensible understanding of real-world manifestations of the concept. Without such an understanding, resources may be misspent, and misguided pressure on academics and universities may emerge. Although significant policy attention has been directed towards the KT, scholarly interest has been lukewarm: only two studies explore the trilateral linkages of the KT at universities and both focus solely on the individual level [*Holmén, Ljungberg,* 2016; *Sjoer et al.,* 2016]. The question of how institutions organise themselves for supporting KT principles therefore remains unexplored. Given the above, we set out to study how the principles of a KT are orchestrated[2] at universities, guided by an exploratory research question: how are the principles of a KT manifested in the daily activity and strategies of different types of universities?

Swedish universities are of particular interest as an object of study. All Swedish universities are expected to cover the three corners of the KT within the same organisation and serve as "research institutes of society" that undertake a broad range of activities from basic research and education to contracted research and training. In addition, all educational programmes are included in the academic system, and all universities are included in the same unified system with equal remits. Furthermore, due to recent reforms, Swedish universities hold a large degree of organisational independence from the state: their rewards system, organisational matrixes and the structure of positions can be decided without governmental approval. This creates an opportunity to study a diversity of institutions within a unified system with similar expectations and opportunities to incorporate the principles of the KT.

Analytical framework

In line with [*Markkula,* 2013; *Goosens, Sjoer,* 2012], we regard the notion of a KT to be a conceptual and normative framework for understanding the creation and dissemination of knowledge as a multifactorial and systemic process that integrates education, research and innovation in a synergic way. The KT may be manifested in a rhetorical or political way, or through the build-up of new structures and processes at the micro (individual or research groups), meso (faculty, departmental or organisational) or macro (national or international policy) levels. The KT builds on the assumption that connections are productive and thus should be strengthened; our starting point is instead that such linkages will be temporary and conditional in the multi-purpose setting that is inherent to modern contemporary universities [*Maassen, Stensaker,* 2011].

To our knowledge, only two scientific studies explore the three-way linkages between the corners of the KT on the level of individual researchers and teachers: Holmén and Ljungberg [*Holmén, Ljungberg,* 2016] find reinforcing spill-overs between the tasks, with research being the task that contributes most, and Sjoer et al. [*Sjoer et al.,* 2016] find that individual perceptions concerning the nature of a task is the main barrier impeding the creation of linkages. However, there are other relevant contributions covering two-way links that help us study manifestations of the KT.

[1] The third corner in the KT has been referred to as the "third mission" or innovation. Although largely overlapping, these concepts are not synonymous. In this paper, we frame the third corner of the knowledge triangle as innovation, since it is the most commonly used term in the KT concept. In the context of this paper, we define innovation as the exploitation of university-based knowledge outside of the academic realm.

[2] By orchestration we refer to the process of interpreting, adapting, arranging for, and implementing the principles of the knowledge triangle.

Firstly, the link between research and education (the Humboldtian model) has traditionally received significant scholarly attention. Studies offer evidence of mutually nurturing links between research and teaching [*Robertson, Bond,* 2001; *Holmén, Ljungberg,* 2016], and task integration [*Colbeck,* 1998]. Concurrently, others show that the Humboldtian ideal is hard to live by. Geschwind and Broström [*Geschwind, Broström,* 2015] provide evidence of a division of labour between staff, and Marsh and Hattie [*Marsh, Hattie,* 2002] demonstrate that there is no significant relationship between research productivity and teaching quality. The debated causes of the divide include the concentration of research and the actual cost-effectiveness of the division of labour at the individual and institution levels [*Clark,* 1997; *Maassen, Stensaker,* 2011; *Pinheiro et al.,* 2014].

Secondly, the link between research and innovation has been explored through studies of research collaboration [*Sonnenwald,* 2007; *Bozeman, Boardman,* 2014], university-industry interactions [*Mansfield,* 1998; *Scott et al.,* 2001; *Perkmann, Walsh,* 2007; *Perkmann et al.,* 2013], modes of knowledge production [*Gibbons et al.,* 1994], the triple helix [*Etzkowitz, Leydesdorff,* 2000], the entrepreneurial university [*Clark,* 1998], the third mission of universities [*Laredo,* 2007; *Pinheiro et al.,* 2015] and the position of universities in innovation systems [*Fagerberg, Verspagen,* 2009; *Jacobsson, Perez Vico,* 2010]. Many such studies describe the productive complementarity [Gulbrandsen, Smeby, 2005; *D'Este, Perkmann,* 2011; *Wigren-Kristoferson et al.,* 2011; *Fogelberg, Lundqvist,* 2012], and underline the embeddedness of innovation in research [*Etzkowitz, Leydesdorff,* 2000; *Pinheiro et al.,* 2015].

However, other studies raise concerns that short-term commercialisation comes at the expense of long-term research and undermines the efficiency of the division of labour between public and private research [*Larsen,* 2011], and even deteriorates academic virtues, such as scientific rigor, objectivity and independence [*Slaughter et al.,* 2002]. Although empirical evidence predominantly shows a positive relationship between commercialisation and research performance, there are notable exceptions: Perkmann et al. [*Perkmann et al.,* 2011] find no uniform relationship between industry involvement and faculty quality, and Buenstorf [*Buenstorf,* 2006] identifies occasional negative correlations between entrepreneurship and scientific performance as well as weak evidence of the benefits from entrepreneurship on scientific undertakings. Indeed, the direction of causality in the link between research and innovation remains unclear [*Larsen,* 2011].

Thirdly, and as to the education-innovation nexus, Holmén and Ljungberg [*Holmén, Ljungberg,* 2015] studied how experiences from innovation feed into education, and vice versa, albeit to a lesser extent. Other studies indicate that conflicting logic hampers this particular form of interaction: Maassen and Stensaker [*Maassen, Stensaker,* 2011] argue that the standardisation of academic programmes within Europe stands in contrast to ambitions of renewal and creativity, which could lead to a divergence of the two.

This review reveals that linkages include both task combinations and mutually reinforcing spill-overs. However, it also reveals tensions, trade-offs and misalignments between formal and informal institutions in the pursuit of creating KT combinations. In exploring the nature of manifestations of the KT, the concept of institutions as formulated by North [*North,* 1990] and Scott [*Scott,* 2014] therefore appears useful as it helps us identify and structure observations. Institutions are the rules created by humans that condition interactions and thus the development of organisations. Institutions may be regulative [*Scott,* 2014], or as North [*North,* 1990] puts it, formal, and include laws, regulations or statutes. They may also be informal and include normative and cognitive dimensions, such as attitudes, beliefs and codes of conduct.

Against the above, we explore the manifestations of the KT as formal and informal institutions at universities at the micro (individual or research groups) and meso (faculty, departmental or organisational) levels, and contrast this against macro (national or international policy) level conditions. Formal institutions' activity encompass the determination of policy priorities, strategy development, work routines, evaluation schemes and other tangible incentive frameworks. Informal institutions in this context include cognitive interpretations of and attitudes towards the KT held by individuals representing different levels (micro, meso or macro), as well as their culture and behavioural norms.

Method

We conduct our analysis through a two-step mixed method approach. Firstly, we search for insight into the conditions of the current Swedish policy landscape concerning the KT using scholarly articles and policy reports from public and private research funding organisations, public agencies, non-profit organisations and interest groups. Secondly, we conduct case studies on three universities selected for their representativeness of the Swedish university population in term of size and type (i.e., comprehensive, specialised or regional). The selected universities are Lund University, Chalmers University and Malmö University. Lund University is one of Sweden's large, comprehensive universities with long-standing traditions and experience in all three areas of the KT, but a clear budgetary focus on research. Chalmers represents a specialised university with ambitious management traditions and extensive industrial collaboration; it is as research-oriented as Lund University, but places a stronger emphasis on innovation. Malmö University is one of Sweden's newer regional universities, where its engagement with the local community (including the city and industry) has been central to the formulation of research and

Table 1. **List of interviewees and their position**

Item	Position
Lund University	
L1	Pro Vice-Chancellor (for external engagement)
L2	Pro Vice-Chancellor (for research and research infrastructure)
L3	Former Vice-Chancellor
L4	Professor (and Principal of the Helsingborg campus)
L5	Professor
Chalmers University	
C1	Director of an Area of Advance
C2	Former Dean
C3	Professor A
C4	Vice principal A
C5	Vice principal B
C6	Vice principal C
C7	Professor B
Malmö University	
M1	Dean and acting Deputy Vice-Chancellor
M2	Vice Chancellor
M3	Research coordinator
M4	Pro Vice-Chancellor

Source: compiled by the authors.

educational programmes; it is also a heavily teaching-oriented university, with roughly two thirds of its turnover based in education.

The case studies mainly build on 17 interviews conducted between November 2015 and November 2016: five at Lund University, seven at Chalmers University and five at Malmö University (M1 was interviewed twice). Interviewees made up a representative sample of individuals with regard to research group, department, faculty and university management level (including Professor, Dean, Pro Vice Chancellor and Vice Chancellor levels), as well as to the universities' three tasks (see Table 1 for details on interviewee positions). The interviews are labelled in numerical order with the initial letter indicating the affiliation (e.g., L1 for the first interviewee at Lund University, C2 for the second interviewee at Chalmers and M3 for the third interviewee at Malmö University). In addition to the interviews, university policy documents and previous relevant studies were reviewed, and a relevant workshop was attended at Chalmers. This allowed us to triangulate our findings.

The contextual policy setting

Ever since the KT concept was introduced during the Sweden's EU presidency in 2009, Sweden has been at the forefront of related policy development [*Benner, Sörlin,* 2015]. The Swedish innovation agency Vinnova was commissioned by the government to operationalise the concept. Consequently, and in line with Vinnova's focus on innovation, the work with the concept has been narrowed down to improving the third mission. Thus, despite the overarching ambitions, Sweden lacks policies and instruments explicitly targeting the KT as a whole. However, there are several different policy groups that influence and relate to KT principles.

Firstly, as many other countries have done, Sweden has placed an increased emphasis on research excellence and concentration, and has therefore significantly increased universities' R&D expenditures [*Bienenstock et al.,* 2014]. The increase is chiefly channeled through the extensive use of funding instruments targeting excellent or strategic research areas and the environment, and through the partially performance-based, excellence-focused research funding scheme for block funding introduced by the government in 2009 [OECD, 2016b]. Consequently, an already strong prioritisation of research was reinforced [*Pinheiro et al.,* 2014]. As advanced research and education is combined at one organisation, scientists can "liberate" themselves from teaching and transfer the task onto individuals with lower research ambitions or less success in gaining research funding [*Carlsson et al.,* 2014; OECD 2016b].

Secondly, in line with international trends, the Swedish education system has undergone a dramatic increase in the volume of students and staff. Between 1985 and 2014, the number of full-time students in Sweden tripled [*Eriksson, Heyman,* 2014]. Even though public funding for teaching has grown, universities' funding for R&D has increased significantly more [Swedish Higher Education Authority, 2015].

Thirdly, policy has encouraged a more systematic way of handling interactions between society and universities, and Swedish universities have actually started to embrace more systematic views, albeit evidence of causal links is lacking [*Benner, Sörlin,* 2015]. Indeed, the historically close societal interaction of Swedish universities has been unsystematic, and revolved around certain individuals, groups or communities. During the 1970s and 1980s, policymakers applied an institutional approach to societal interaction [*Benner, Sörlin,* 2015], setting up publicly funded programmes for interactions between universities and industry and "intermediaries" (e.g., offices and technology parks), which created a strong focus on the business sector in general and technology-based firms in particular.

Fourthly, a scattered research funding landscape together with the dispersed management and funding of research, education and innovation creates significant challenges from a KT perspective. Sweden's research funding system is characterised by a large number of funding organisations that mainly target selected research groups or individuals who obtain considerable resources and leverage [*Jacob,* 2015]. Changes in strategy occurred through specific R&D programmes that thus yielded effects that are limited to specific research groups or academic disciplines [*Benner,* 2013]. In addition, since the late 1990s, Sweden has deregulated its academic career system: individual universities control the content of positions, including the relative shares of research and education, as well as funding sources. It is quite common to have permanent positions on the basis of external funding alone, with little or no teaching tied to them [Government of Sweden, 2016]. Consequently, much of the steering power lies in the hands of research funding agencies and research groups.

Fifthly, in line with international arguments that increased autonomy strengthens research performance and societal connectivity [*Aghion et al.,* 2008], Swedish universities have seen their autonomy increase. Consequently, the expectations of task integration between the three components of the KT fall on universities themselves.

The Swedish university population includes three types of universities: comprehensive, specialised and regional universities. The three cases are selected as exemplars of these categories. An overview of key statistics is provided in Table 2 below, illustrating the differences in character of the three universities.

Lund University is one of Sweden's largest comprehensive universities with a long tradition of embeddedness in and interaction with its local communities. Although the university caters to a large number of students, it is strongly research-oriented as two-thirds of revenue come from research (see Table 2). Chalmers represents a specialised technical university with extensive and long-standing ties to related industries[3]. It has ambitious management traditions and is even more research-oriented than Lund, but with a stronger emphasis on innovation, as revealed by the relatively large share of collaborative public research funding (see Table 2). Malmö University is one of Sweden's newer regional[4] universities, where the interaction with the local community (including the city authorities and industry), particularly with regard to articulating the demands of the local labour markets and the public sector's demand for skills in education and healthcare, has been central to the formulation of research and educational programmes. In contrast to Lund and Chalmers, Malmö is heavily teaching-oriented with roughly two-thirds of its turnover in education (see Table 2).

In the following cases, the manifestations of the KT (in terms of informal and formal institutions) and observed challenges related to enabling KT ties are explored.

Lund University

Founded in 1666, Lund University (LU) is one of the oldest universities in Northern Europe and is ranked among the top 100 in the world[5]. LU is comprised of eight faculties[6] located on campuses in Lund, Helsingborg and Malmö. LU is also home to a number of institutes, specialised research and innovation communities, and platforms for societal interaction. Two major facilities for materials research are currently under construction in Lund: the MAX IV Laboratory (a synchrotron radiation laboratory) and European Spallation Source (ESS, a European facility that will be home to the world's most powerful neutron source). These will be of decisive importance for materials and life sciences and for industrial development.

Informal institutions

At LU, the attitudes towards and the perceived value of pursuing each task of the KT vary — resulting in fragmentation or unbalanced linkages between the tasks.

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3 Other specialised universities in Sweden include agricultural and medical universities.

4 The term "regional" may be seen as a misnomer, as these universities recruit students and faculty as broadly — sometimes even more so – than comprehensive and specialised universities. The term "regional" indicates that they were founded as part of the regional mobilisation of resources after the industrial crises of the 1970s and 1990s.

5 LU ranked 70th in QS ranking 2015/2016 and 90th in Times Higher Education World University ranking 2015/16.

6 Engineering (LTH), Social Sciences, Humanities and Theology, Economics and Management, Medicine, (Natural) Science, Law, Fine and Performing Arts.

Table 2. **Key figures for the universities for the year 2014**

	Lund University	**Chalmers University**	**Malmö University**
Year founded	1666	1829	1998
Vision	"to be a world-class university that works to understand, explain and improve our world and the human condition"	"Chalmers for a sustainable future"	"A world where diversity, knowledge and creativity is transformed into action for sustainable development"
Full time students (Undergraduate and graduate students)	27 702	8 926	12 340
of which graduate students	7 146	3 137	1 438
Full-time faculty	2 997	1 173	753
Professors	708	201	77
Total revenue	7.5 million SEK (app. 815,000 EUR)	3,4 million SEK (app. 370,000 EUR)	1,3 million SEK (app. 141,000 EUR)
Research revenue as a share of total revenue (%)	67.6	71.5	20.8
Share of block funding (research and education) (%)	56.2	48.4	75.7
Share of public funding requiring collaborative research with actors outside academia (2013)* (%)	9.7	22.5	14.8

* This includes funding from research funding organisations that require the participation of non-academic actors, such as from Vinnova or the Knowledge Foundation. This data was provided directly by Vinnova and includes an elaboration by Vinnova on data from Statistics Sweden.

Source: [Swedish Higher Education Authority, 2015].

Central management at LU expresses the importance of the interplay between research, education and innovation — highlighting the university's vision "to be a world-class university that works to understand, explain and improve our world and the human condition" [Lund University, 2012]. At the same time, central management recognises that the faculties have no common interpretation or way of operationalising the KT.

"On an ideological level, the importance of the interplay is well understood and embedded in our strategy and employees' understanding. However, there is a long way to go before we realise our aim of having "complete" learning environments — with a well-functioning and balanced integration between research, education and innovation — across our faculties." (L1)

On an individual (or group) level, there is the general perception that research, education and innovation should be mutually reinforcing activities, as more "integration" can enhance the quality of each aspect. Yet the approach for linking the various elements differs broadly across LU's faculties and departments. For some faculties or disciplines with more direct and practical application to societal issues (e.g., engineering or social sciences), there is a more natural integration and responsiveness to society's needs. This has led to differing levels of competence and experience across the faculties in engaging with "outside" actors in the local/regional system and understanding and addressing their needs.

"Certain institutions are doing well to integrate research and education. These are often the same environments with well-defined strategies for interacting with society. In other cases, the three missions are developed in isolation of one another." (L2)

Many interviewees highlighted the importance of the culture and attitudes towards the different dimensions of the KT. The general perception is that efforts to integrate research, education and innovation are not recognised or rewarded.

"People don't get paid or recognised in any way for the third mission. Third mission activities are not seen as enhancing research and educational tasks, but rather taking time away from "core" tasks such as securing research financing." (L2)

"LU is a rather traditional university – where a focus on research excellence has top priority. It is not easy to change a culture or an orientation towards research excellence. It's a long-term process, but also necessary to undertake to ensure that LU is well-positioned in the future." (L5)

Formal institutions

The central management at LU is comprised of a Vice Chancellor, a Deputy Vice Chancellor (responsible for education and international relations), a Pro Vice-Chancellor for Research, a Pro Vice-Chancellor for External Engagement, and a University Director. Each of the eight faculties has similar management structures, with a Dean and Vice-Deans who hold separate responsibilities for education and research (and, in some faculties, for innovation and/or international relations). The management of financial resources and personnel is highly decentralised.

The Strategic Development Plan for LU 2012–2016 sets out the overall goal of "the highest quality education, research, innovation and interaction with society" and outlines four strategies for achieving this goal (cross-boundary collaboration; internationalisation; quality enhancement; and leader, teacher, and employee excellence). These strategic ambitions are reflected in a number of recruited positions or support functions within the University's central administration, which were initiated or further developed under the leadership of the previous Vice-Chancellor.

> *"It is important to work proactively when developing collaborative relationships. The central administration can play an important role as a "development motor". [LU management] developed a number of structures, including LU Open[7] and the Research and Innovation Council of Skåne, recruited personnel, and initiated activities to strengthen the interplay between research, education and innovation." (L3)*

At the start of 2015, the current Vice-Chancellor and leadership team began to develop a new development strategy for LU and to undertake a number of changes to central support functions, including the delegation of responsibility for initiating and leading cross-boundary collaborative activities from the centre (through LU Open) to the faculties to ensure stronger embeddedness in core operations, that is, research and education [Lund University, 2015].

> *"All faculties should have their own platforms for developing relations with external actors, proactively initiating and following up on collaborative projects. It's understandable that the central level may be involved in initiating some platforms, such as cross-disciplinary ones, but these should be integrated and developed within the faculties and departments." (L4)*

> *"There are examples of 'integrated knowledge triangles' within departments, but cross-disciplinary programmes or platforms are rare. The central administration has limited resources to support cross-disciplinary efforts, and those activities that have been initiated are not always viewed in a positive light. It seems to work better if one faculty has the lead – with the responsibility of involving other faculties. This ensures structures are stable and are perceived as 'core'." (L2)*

The new strategy will play an important role in signalling LU's priorities for a stronger interplay between research, education and innovation (guiding the respective strategies at the faculty level). There is also a need for more concrete guidance on how the university will work operationally with the KT.

> *"The university leadership needs to provide a strategic direction, support structures and incentives, as well as visibility of good examples. [The integration of research, education and innovation] won't happen by itself." (L1)*

> *"There seems to be a need for simplifying and clarifying the central support functions — clearly communicating a service offered to the recipient faculties and departments." (L4)*

In addition, the central administration and faculty management see a need for changing the financing system to enable better integration between research, education and innovation. The necessary changes include the flexible use of existing budgetary allocations and financial support (or other incentives) for social and cross-disciplinary collaboration.

> *"It is difficult to finance the development of new educational programmes or research areas, as the financing system does not allow for the flexible use of budgetary allocations in research and education. A strengthened integration between research, education and innovation needs to be not only interesting, but also financially viable." (L2)*

> *"There should be better incentives and financing for working with the third mission. It is important to have accessible financial support or seed money to start new things and weave in the third mission as part of educational and research activities." (L4)*

> *"Collaboration across disciplines and with external actors [on education and research] can be strengthened through financing — or by making collaboration a requirement for accessing [certain] research financing." (L5)*

Observed challenges in realising knowledge triangle links

There are two main tensions that challenge the orchestration of the KT at LU: the contradictions between the tasks, and the clash between the role of the central administration in relation to the faculties.

[7] LU Open was initiated in 2011 as a development unit (under the central administration's section for research, collaboration and innovation) and specialises in matching external stakeholders with researchers and students, and designing and executing projects with the objective of solving complex challenges.

There are different ways of interpreting and implementing the KT across the faculties of LU. In general, most effort is focused on securing financing for and producing high quality research. Education is also a core priority, but may be viewed as a "second" priority after research. Innovation and social interaction is conducted on a very ad hoc basis (driven by individual values and passion, mostly based on free time). The result is a fragmentation between the various tasks and a lack of clarity about the benefits of strengthened integration.

The distribution of support functions and collaboration platforms between the central and faculty levels of management also causes problems. Thus, LU seems to be navigating between different integration models. One is the centralised model (including formal institutions such as LU Open, which actually initiate activities). The other is the current distributed model that anchors notions of integration among its faculties (which have very different structures, financing models, and attitudes towards both the importance and the operationalisation of the KT). This pluralism results in diverging views on how resources should be used and which activities provide the most value, as well as barriers to establishing cross-disciplinary collaboration for LU as a whole.

Chalmers University of Technology

Chalmers University of Technology (CUT) is a research-focused technical university situated in Gothenburg, Sweden's second largest city. Gothenburg has a rich industrial history and high R&D intensity [*Fogelberg, Lundquist,* 2012]. CUT's industrial embeddedness is reflected in its position as the fifth university worldwide (2015) with the highest share of industrial co-publications according to the Leiden Ranking. CUT was founded as a vocational school in 1829 through a donation by an industrialist, but soon became state-owned. In 1994, the university was transformed into a private foundation with greater autonomy than other Swedish universities [*Jacob et al.,* 2003]. Education (chiefly engineering) and research is conducted within 18 departments.

Informal institutions

At CUT, there are diverse cognitive understandings of what a KT includes. Consequently, attitudes towards its usefulness vary, as illustrated by two vice presidents:

> "*Through […] a productive KT, we can create arenas for change […] We have to train our organisation to enable this.*" [*Holmberg,* 2015]

> "*We do not work with the knowledge triangle [at CUT] because we do not think the concept fits with our integrated picture of the utilisation of research and education. The KT polarises the three tasks by placing them in corners." (C6)*

A first aspect in which individual's understandings of the KT differ relates to the concept's novelty. According to some interviewees, it is nothing new:

> *"I feel that I truly work within the KT, but I seldom use the expression, maybe because it's self-evident." (C1)*

Others emphasise that the concept brings much needed attention to the third mission (C2, C3).

A second aspect concerns whether the realisation of the KT implies additional activities (C4), or the reworking of existing tasks:

> "*The relationship between education and innovation should not be about activities that 'season' education […] but about revising entire educational programmes on the basis of universities' wider societal role." (C5)*

A third aspect concerns diverse perceptions of the third mission. While some equate the third mission with innovation and focus on its link to research (C4, C7), others emphasise wider societal responsibilities including sustainability (C5, [*Holmberg,* 2015]).

This diversity in the understandings adheres to the various cultures and values of individuals that both reflect CUT's industrial and entrepreneurial spirit, and traditional academic norms. CUT researchers with strong traditions of doing basic research in industrial contexts embrace the integration of academic and applied research cultures [*Fogelberg, Lundquist,* 2012]. Others mainly identify with academic norms and perceive integration as problematic [*Jacob et al.,* 2003; *Fogelberg, Lundquist,* 2012]. An interviewee illustrates the latter view:

> *"Some researchers need to go upstairs in the ivory tower […] and only come out every now and then to say things that amaze everybody […] but if we only direct our research toward the needs and issues of specific actors […] what about the future societal needs?" (C7)*

The link between research and education is often combined in the same persons. However, further specialisation emerges partly due to the higher status of research that materialises through attitudes and norms (C3, C5). The link between education and innovation are often driven by the commitment of teachers who use their networks to introduce practical elements (C3). The interest and motivation of students is also significant (C5).

Formal institutions

CUT applies a process-oriented management model, where vice presidents lead education, research and utilisation, respectively. Education has its own organisation that procures courses from the departments that employ researchers and teachers.

On top of these layers are the eight Areas of Advance (AoA)[8] — an organisational structure introduced in 2010 with the vision to "match [CUT] scientific excellence to global challenges" and the mission "to create a unique integration of the KT" in thematic areas [CUT, 2011, p. 4]. The AoA vice president holds the formal responsibility of implementing the KT. The AoA were the result of a government initiative to strengthen strategic research areas that provided AoA with significant funding. A national evaluation of the initiative praised the AoA and recommended increased funds [Swedish Research Council, 2015]. Lately, rhetorical KT references in relation to the AoA have faded (C6) and the AoA have developed into platforms for third mission activities and cross-cutting research targeting scientific excellence (C1, [CUT, 2016]).

The AoA is a unique initiative but a somewhat natural trajectory for an ambitious university with strong management and industrial traditions. Over the course of the last few decades, CUT has strived to transform itself into an entrepreneurial university and has established innovative structures such as a venture capital firm, a seed financing company and an entrepreneurship school [*Jacob et al.,* 2003; *Fogelberg, Lundquist,* 2012]. This has successfully integrated innovative research, entrepreneurial education and action-based training [*Jacob et al.,* 2003]. However, these structures emerged as ad-hoc experiments without clear guidelines under diverse legal structures and were steered by strong individuals. This created opacity and fragmentation [*Jacob et al.,* 2003] that increased with additional, often government-induced, third mission initiatives. One example is the innovation office, a service function installed in 2010 targeting research utilisation. Despite revisions during the last decade, the sense of opacity somewhat remains. Thus, the current vice president of utilisation has a strong focus on integration and coordination (C6).

Despite CUT's AoA and innovation support structure, management schemes seldom target KT integration. Recently (2016), CUT introduced a faculty fund allocation system and guidelines for staff appointments that account for the three core tasks. However, task integration is not a priority and some researchers and deans argue that staff appointments will become less flexible and that the emphasis is on traditional academic excellence at the expense of societal engagement (C2, C3). Relevant management schemes targeting the third mission also have appeared within individual departments. Examples are the appointments of vice deans responsible for the research utilisation, the development of long-term strategies and key performance indicators as well as employee support and encouragement through salary negotiations and work procedures ([*Hillemyr et al.,* 2015], C2).

Observed challenges in realising knowledge triangle links

Although CUT's AoA and innovation efforts have been advantageous, significant difficulties related to realising the KT remain. Firstly, the division of roles between the departments, the infrastructure for innovation and the AoA is unclear. The AoA have responsibility regarding the KT, but the departments hold the human resources and are responsible for core tasks. KT connections created by AoA appear to be rare (C1, C7). Rather, connections mainly emerge due to intra- departmental research (C3, C1). As a researcher put it:

> *"We had developed our connections [before the AoA]. We had the applications, the international cooperation, the government relations, etc. […] For us, [AoA] has been more of a hassle and created ambiguity […] it's getting so much more complex, and you do not know what to expect from whom anymore." (C7)*

Secondly, tensions stem from the perceived distance between management and researchers. Some faculty think that that management's goals are over-ambitious and inaccurate:

> *"I think management is over-ambitious […] management is trying to steer things that they have little influence over, and limited information about." (C7)*

> *"The management is somewhat inconsistent […]one moment we should focus on innovation, the next we should be excellent […] but we know our business, it is through [the faculty] that the knowledge triangle is realised." (C3)*

[8] The areas are Energy, Materials Science, Nanoscience and Nanotechnology, Production, Transport, Life Science, Information and Communication Technology and Built Environment.

Thirdly, although tension between research and innovation at CUT have been perceived as minor [*Fogelberg, Lundquist,* 2012], there is still some distance between support structures and real needs (C6). While some faculty utilise the support to act entrepreneurially, others think that the structures signal a too narrow a view on utilisation (C7). Also, there is some divergence concerning the focus on excellence:

> *"I notice an augmented pressure to strive for academic excellence, but there are significant trade-offs […] I am concerned because this increased pressure may potentially hinder societal engagement […] and the development of new research venues." (C3)*

There are however also concerns about the ability of academia to conduct unbiased and curiosity-driven research in the light of third mission ambitions (C7).

Fourthly, significant tensions concern education:

> *"The education task has at times been taken hostage by innovation and research players […] that have influenced the content of education programmes, dominantly based on perspectives from research and innovation that aren't necessarily in line with those of education […] Strengthening the connection between education and the third mission is not about matching students to the direct needs of beneficiaries or introducing individual elements where students are utilised to reach [innovation goals]. Instead, [strengthening the connection] should be about producing students who can formulate problems that address societal challenges and critically observe society to push societal development in the right direction." (C5)*

The organisation for education and the AoAs have both worked with integrating societal engagement in education, but in a rather uncoordinated and unsuccessful way (C1, C5, C2). However, interviewees are sceptical towards a stronger integration of education into the AoA due to the risk of increased complexity.

Finally, tensions have emerged between faculty or department initiatives, external initiatives, and university-wide strategic schemes — mainly due to overlapping missions, resources and mandates. For example, the innovation office was created as a government induced add-on organisation. Although their activities have been significant for third mission developments, they have not yet been successfully integrated (C1, C6).

Malmö University

Malmö University (MU) was founded in 1998 as a state accredited university college, granting it powers to award undergraduate and master's degrees and with a restricted remit for the award of doctoral degrees. MU is the ninth largest higher educational institution in Sweden with five different faculties, providing over 100 programmes of study and 350 courses to well over 20,000 students and almost 200 graduate students. In 2016, it was announced that MU would become an accredited "university" in 2018, which, inter alia, means that it will be empowered to award doctoral degrees without restrictions, as well as receive increased state subsidies for research.

Informal institutions

Interviews contained few direct references to the KT itself, but societal interaction was a recurrent theme in the self-understanding of MU. One interviewee (M1) described MU as "quick and flexible", keen to engage with societal challenges such as migration and inequality. Societal engagement thus emerged as a core value for Malmö, including "social innovation" in a very broad sense: "it's about processes, not things — meetings, feelings, experiences" (M1). This attitude helps to cement and embed KT principles within the university, and students and faculty are inspired by interactive attitudes and opportunities. Hence, the connections between education, research and innovation are viewed as an integral and attitudinal part of all activities at the university. The approach is more cultural than formalised:

> *"I don't think in a triangle way — I try to look at the strategy and the vision that we have — dynamic system thinking is more useful here. A triangle model is perhaps not so helpful."* (M2)

In line with the broad understanding of the university's role, its representatives articulated quite eclectic perspectives on innovation. One of the interviewees (M3) emphasised a belief that there should be a variety of forms of innovation rather than merely commercial applications. Involving external parties in the early stages of research processes is seen as having an impact on what "knowledge" is for MU and is a valued form of interaction.

Achieving this is not seen primarily as a matter of drawing on experiences developed elsewhere; important knowledge on societal collaboration resides within the university itself, and there is a need to generalise these experiences beyond the specificities of these individual undertakings (M1). One way in which Malmö could better structure their KT activities is by generalising the experiences made inside the university (M2). More research could be done, for example, to evaluate collaborative projects in a way that forms a subject for research in itself. Another way to enhance the structure of the KT is to move away from spontaneous interactions with societal stakeholders to a more focussed and conscientious model, where the rich and dense societal networks of MU could be translated into research strongholds:

> "*People are very committed to solving societal challenges at MU, it is in their mindset. People already have the drive, although they need to develop awareness about relating work to research in a more focused way. Research at MU needs to be boosted via these collaborative projects.*" (M2)

Regarding the topics for societal engagement, one interviewee stressed that social sustainability could form a particularly good platform, relating strongly to the KT as well as to many different societal challenges, while still putting the university at the centre (M4). This approach has also been used in forming alliances within different calls based on principles of "grand challenges", for instance within the European Union Horizon 2020 programme (M1).

As a very recently established university college, MU has been more heavily focused on teaching, particularly professional education, and practical, socially contextualised outcomes. MU's identity is shaped by comparisons with the older universities of Sweden, which tend to be research-focussed with a broader educational profile; in contrast, MU is focussed on professional training and expectations emerging from a societal context.

> "*We are more heavily focused on education, particularly professional education. As a relatively recently established university, we put an emphasis on these more practical, socially contextualised aspects.*" (M4)

This is demonstrated also in the university's recruitment patterns. As an example, one third of MU doctoral candidates are employed outside of academia, most often working on their doctorate on a part-time basis. This brings in a lot of outside influence, giving the university a clear "imprint" outside in the world beyond its doors and providing opportunities for obtaining commissioned research contracts (M3).

Formal institutions

MU leadership brings together different backgrounds that combine many years of public organisational experience, private sector management and experience in running long-term collaboration activities with societal actors (M1, M2, M4). The MU leadership see the combination of these sectors as a major driver of quality in education and research. Societal challenges form the core mission for the entire university, rather than being peripheral add-on activities (M2, M4). Even though models like the KT are seen as somewhat too rigid and unimaginative to function as organisational blueprints, they serve as mementoes and ideals stressing the virtues of aligning the three missions. There are also tangible organisational signals for the significance of societal connectivity, for instance, the university functions as a national hub for social innovation. This is an important profile for the university and is seen as a way to attract potential external funding and collaborators (M2, M4).

There is much innovative work being done by staff and students that senior management would like to harness, in particular by evaluating their collaboration activities in more detail and therefore providing opportunities for further research projects (M2, M4). As societal interaction is such a strength at Malmö, "*there is a huge communication task ahead*" (M4) concerning how to raise the profile of these kinds of collaborative activities with civic society, explaining what they do and how they are beneficial. One example is MU's active engagement in crime prevention research, a key issue for the long-term viability of Malmö as a city (M1).

MU continues to integrate the KT elements predominantly through its overall value-based approach to innovation and inclusivity within its internal systems for recruitment and promotion. Its own merit system for employment takes into account experience with innovation and collaborative work (M2). The university has a model for the distribution of faculty research funding based on an average from the last three years' external funding that does not discriminate between different sources (e.g. EU, regional or corporate). This becomes an incentive for making contacts with outside partners. Another example is trainee teachers working in the local community who are being used as "change agents" by creating "innovation hubs" for education, who subsequently becomes links that create research opportunities (M4).

Senior management would also like to create a common space where faculty, staff and students can "get out of their daily routines in life and work" and become more open to communication with external partners. MU has also developed value-based leadership at the Anna Lindh Academy[9] with a special focus on large public and private organisations (M2, M4).

A core aim at MU is to extend research into society and bring society into research. The principles of embedding knowledge flow between actors is "not really top-down" and is "built-into" the core activities of education and research (M3). Often MU works with the NGO sector and this kind of cooperation is embedded in the university, becoming the "regular way of thinking and acting" (M3). Collaborative efforts are a serious added dimension to teaching and research, and experience with collaborative activities is now seen as an important criterion during the recruitment process.

[9] "Anna Lindh Academy was founded with the aim to contribute to a new generation of value-driven leaders who promote human rights and democracy both in Sweden and internationally". (http://annalindhacademy.se/om-anna-lindh-academy)

Observed challenges in realising knowledge triangle links

The many societal interaction initiatives taking place at MU are being used to strengthen the university's research base which is currently scattered: some areas are well-endowed and resourceful whereas others are nascent or non-discernible. Much depends on the effectiveness of measures adopted at various levels, including national policy: Senior management feels that better opportunities for interaction and innovation projects are needed and that more than just economic goals should guide the steering mechanism of research funding at the national level (M2, M4). This may, however, be partially alleviated by MU's elevation to full university status in 2018.

Hence, MU straddles two positions: wanting to expand its research basis (which would necessitate an adherence to the current model of competitive funding) but also securing a protected and growing space for interactive activities, which would cater to a broader constituency of interests. According to MU's leadership, social innovation is MU's niche in the Swedish university system. It has different needs from other forms of innovation, and specific tools, goals, financing and structures are required to serve this purpose (M2, M3, M4).

Sweden faces structural problems, such as funding for higher education, particularly in terms of facilitating societal engagement. According to MU's leadership, all interested parties must come together to solve societal problems, however, currently there are not enough incentives as funding is lacking. Also, the feeling is that the current funding scheme favours the funding of more traditional universities for structural and political reasons (M2). In addition, at MU 80% of the revenue is dedicated to education and 20% to research, so there is a great imbalance and limited resources to build a foundation for doctoral education and multi-faceted research environments. Thus, MU's leadership sees the integration of funding for education and research as necessary to better align the various tasks of the university.

Discussion on the paper's findings

The previous section revealed the approaches to orchestrating the KT at three universities. CUT is purposefully orchestrating the KT through a matrix scheme. Difficulties have arisen as the new structure complicates resource flows and governance, both vertically between organisational levels, as well as horizontally between the three KT components. LU has a weak steering centre and considerable variation between its different constituent parts. The organisation of KT activities reflects these differences, where a recently adopted top-down approach co-exists rather uneasily with bottom-up activities, and where some faculties have profound and well-elaborated models, others have only minimal experience. MU has predominantly been focused on education. As a result of limited research funding, the administration has been forced to find innovative ways of seeking external funding, primarily through interactions with the local community. However, contradictions exist between current structures for research funding in Sweden and the principles of KT integration that MU aims to realise.

Combined, the cases leave us with four key observations on the manifestation of the KT at universities. Firstly, there are contradicting views within the universities related to the third mission and the KT. This observation is in line with those of Sjoer et al. [*Sjoer et al.,* 2016] who identify a great diversity in perceptions that actors have of their tasks, and that not all actors adhere to KT principles. While this may be expected at a broad and decentralised university such as LU, or a young and evolving university as MU, the observation of contradicting views at a management-driven university such as CUT is less expected. When comparing the experiences, funding patterns and mandates of interviewees with their own views, we find indications of how the fragmented Swedish higher education and research system contributes to this diversity. The separated funding streams (for the three tasks, and for research in particular) each channel divergent views on the third mission and task integration, which strongly influence concerned actors at the universities. A clear consequence observed in all three cases is that innovation is conducted on an ad hoc basis, either enabled by different funding actors or driven by individual initiatives. The result is a fragmentation between the various tasks and a lack of clarity about the benefits of strengthened integration.

Secondly, it is clear that education has fallen into second place and that the focus on research excellence and attaining research financing has overshadowed the incentives of an integrated KT. These findings are in line with Geschwind and Broström [*Geschwind, Broström,* 2015] who found signs of a growing division of labour between teaching and research at Swedish universities. However, the task separation and research dominance is less clear at MU. Dominated by educational activities and adhering to a civic context, MU does not fall in line with traditional academic expectations in the same way as CUT and LU do.

Thirdly, the on-going macro level process of professionalisation and integration of the third mission has been challenged by the drive for research excellence. At LU, challenges have varied with the diverse prevailing conditions within different faculties and groups, while at CUT the conflicts regarding goals between research and the third mission are clearer. MU has provided good examples of KT principles in practice by using societal interactions to maximise investment in research, but still faces difficulties dealing with existing research funding structures. For instance, MU exemplifies how creative approaches to KT integration through societal engagement can be underfunded due to a preoccupation by funding bodies with industrial collaboration over civic engagement, or when the societal impact is disregarded altogether.

Finally, the universities have used their increased autonomy in different ways with diverse consequences for orchestrating KT principles. Following its proactive management tradition of responding to external expectations, CUT has continued on the road of creating structures and defining processes by mediating visions of KT integration through the new organisation of AoA. However, vertical contradictions have emerged due to the unclear distribution of mandates between overlapping structures, and because incentives for researchers to strengthen KT principles at the individual level are not in line with political ambitions at the institutional and national levels. LU has mainly redistributed the increased autonomy to the faculties by increasing their mandate. This has led to a more dispersed orchestration where KT initiatives must emerge in a bottom-up manner to gain legitimacy. The result is a federation of faculties that are not directed in a uniform way. Consequently, the decentralised (and autonomous) faculties further exacerbate the aforementioned division between the KT elements due to the pursuit of excellence. MU is more adaptable given its youth and modest size, but is however limited by its rather small resources. The result is promising visions combined with the potential for being an evolving university species, but a lack of strength for execution.

Conclusions and implications

This paper deals with how universities blend their key tasks. We set out to study how KT principles are manifested in the organisation and strategies of different types of universities. The exploratory approach has provided us with rich descriptions from three universities. We observe great diversity in the way in which the principles of KT (bringing together education, research and innovation) are orchestrated at the universities, both in terms of informal institutions such as interpretations and attitudes, and in terms of formal institutions such as articulated strategies and incentive schemes. On the macro level, the KT remains a policy priority and living concept, yet task integration is increasingly expected to be arranged by the universities themselves. Our study reveals the limited ambitions from university management teams to forge new combinations of remits. This in turn mirrors the structure of policymaking in Sweden, where the areas of research, education and innovation have been compartmentalised in terms of funding and governance. As this structure trickles down to the individual and group level, we observe that the articulation of tasks is weak. What we do find is that some individuals take on the task of aligning the three missions despite the obstacles, and thus serve as role models and KT exemplars. We also observe the difficulties as the responsibilities of operationalising the KT often fall upon individuals who sometimes lack the mandate and resources to create enabling conditions and tackle divergent expectations. With these findings, we make a significant empirical contribution to the understudied phenomenon of the KT. To sum up, our major empirical observation is that there is a misalignment between the political goal of implementing the KT and the actual policy mechanisms of the key components. Despite the ambition to reduce the political regulation of universities, the resource flows (and concomitant evaluation and assessment criteria) foster a compartmentalised strategy.

These observations offer implications for policymakers and universities. A key group of actions concern supporting the development of the knowledge needed to fill aforementioned gaps. If future research indicates that we are in fact to create balanced and mutually beneficial links between research, education and innovation within a single university, we need to create a reliable, sustainable and reasonably adaptable (allowing for variation) operational model of the KT, to serve as a flexible starting point for the articulation of the different tasks. Our results suggest that this would require extensive and profound changes in the Swedish academic system. The increased resources and autonomy that the sector has experienced so far has not proven sufficient incentives to foster better ties; indeed, it could be argued that they were better aligned when state regulation was more pronounced. Initiatives for change cannot only emerge through external funders' initiatives and programs, but must also stem from the universities themselves. This would require an academic leadership that, together with the collegiate, could formulate and implement the ambitious goals and strategies required to realise a truly productive KT.

These findings also raise questions for further research. Firstly, a significant but methodologically necessary limitation is that we see the KT linkages as a given in the setting of contemporary universities, form and take them for granted as our point of departure. Consequently, what remains is the question of the actual cost effectiveness of the division of labour vis-à-vis the advantages stemming from the integration. Secondly, it is unclear whether the university is the most suitable level at which the KT should be orchestrated.

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The Effect of Talent Management Process on the Research Performance of Faculty Members with the Mediating Role of Organizational Justice

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Abstract

The research performance of faculty members is one of the main criteria for measuring a university's overall performance, and universities and higher education centers seek to improve research because of their purpose and their commitment to various parts of society. The present research aims at determining the effects of the components of perceived talent management on the research performance of faculty members with the mediating role of perceived organizational justice. The research is a correlational-descriptive study based on structural equations and its statistical population consists of the faculty members at the University of Isfahan, Isfahan University of Medical Sciences and Isfahan University of Technology.

For the sample size, using the SPSS Sample Power software, of 562 individuals 130 were selected using stratified random sampling proportional to sample size. For data collection, faculty members' research performance record, a talent management questionnaire and a perceived organizational justice questionnaire were used. Convergent validity for both questionnaires (AVE) was calculated to be more than 0.5 and the reliability of both questionnaires using Cronbach's alpha coefficient was calculated to be more than 0.75. Data analysis was performed using the Smart PLS 3.2.6 statistical software.

Findings indicated that the components of the variables of perceived talent management and perceived organizational justice account for a total of 61% of the variance of the variable of research performance variable and the mediating role of the variable of perceived organizational justice variable was found to be insignificant. As a result, it can be said that the improvement of talent management processes can lead to increased faculty members' increased sense of organizational justice and ultimately improved research performance.

Keywords:
perceived talent management;
perceived organizational justice;
research performance;
faculty members.

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Universities and higher education centers are important organizations that play a strategic role in accomplishing a country's goals and are expected to create knowledge and educate a specialized and committed workforce required by the country. Here, faculty members are considered the critical factors determining the country's education system and their performance requires serious study and attention. One of the key factors of the productivity of universities and their employees and the criteria for evaluating that productivity is the academic research performed by university lecturers. Players on the higher education market strive to improve their research indicators in line with their goals and obligations to society at large. According to Zainab [*Zainab,* 2000], research performance will strengthen society's confidence in a university, increase the university's prestige and lend a synergetic effects to the development of science and creation of knowledge.

Ramsden [*Ramsden,* 1994] believes that the critical challenges facing universities include faculty members' teaching responsibilities, research performance, and research quality and resource constraints. Research is closely related to the quality of education, and in recent decades has received much attention. Levin & Stephan [*Levin, Stephan,* 1998] believe that people who evaluate the performance of educational institutes, have many concerns about future research quantity and quality. Research performance for the promotion of faculty members is a necessary component, and when assessing the career advancement of these individuals, studies performed by them become critical. Other key aspects for assessing faculty members and their prospects for promotion are their level of knowledge, research performance and received rewards [*Badri, Abdulla,* 2004]. Universities and higher education institutions seek to improve the research performance of their faculty members by taking measures such as holding training workshops for them, providing study opportunities, giving them material incentives as well as incentives for self-improvement, while promoting their academic position in society at large. Gething & Larthaepin [*Gething, Larthaepin,* 2000] state that evaluation of the performance of faculty members usually takes place through peer review of their published papers, and evaluating one's participation in academic conferences and research projects. While teaching and other activities are evaluated successively, faculty members can only achieve success in their educational duties once they have already established themselves as successful researchers, who can then use their research results in the classroom.

On the other hand, according to recent studies, several factors affect individual and organizational performance, including talent management methods at organizations [*Kagwiria,* 2013]. Salehzadeh & Labaf [*Salehzadeh, Labaf,* 2011] consider the reasons why there has been such a focus on talent management in recent years. They considered the direct relationship between talent management methods and superior organizational performance, the use of talent for value amid such changing factors as the complex and dynamic business environment, increased expectations from the board of directors, the change in employees' expectations, and the evolving structure of workforce.

Therefore, the talent management system at universities must observe heightened standards for the employment of faculty members. This system must also identify and attract the best academic talent and ensure proper conditions for the employment of enthusiastic individuals to become members and cooperate in university faculties. In fact, talent management is the most important competitive advantage at modern organizations and the identification of talent is considered the most important task for human resource management [*Sayadi et al.,* 2011].

Huselid, Beatty & Becke [*Huselid et al.,* 2010] state that all individuals have certain talents that must be uncovered and identified. By using talent management, it is possible to ensure that each employee will be placed in a position tailored to his/her special talents and abilities.

Sweem [*Sweem,* 2009] believes that talent management is an intelligent approach to the attraction, development and retention of experts and the use of their talents and competencies to meet an organization's needs and achieve present and future goals. Talent management is a collection of designed processes that guarantee employees' proper placement at an organization. In other words, the right person will be in the right job at the right time.

Various talent management models in the literature have been designed by various experts and theorists, and in each of these models, different elements have been highlighted as the most important for organizational and environmental demands. A model designed by Peter Cheese, Robert Joseph Thomas, and Elizabeth Craig [*Cheese et al.,* 2008] in this field includes five main components that indirectly cover other models. The first of these five main components is "defining and identifying talent needs": the first step in creating a human resource strategy is to fully understand an organization's development strategy and determine the number of personnel and which competencies and skills are needed for effectively reaching long-term goals. Most of all, this involves an analysis and clear understanding of the organization's available talents. The second one is, "discovering talent sources", which involves defining and identifying talent needs based on the organization's goals.

The third component is "developing talent potential", which is the ability to continuously develop individual and group knowledge, skills, and behavioral patterns to improve the overall capabilities of the organization as a whole. In other words, talent development should guarantee that employees continuously acquire new skills and abilities, expand the opportunities available to them and prepare them to accept new roles and responsibilities [*Cheese et al.,* 2008]. According to [*Rezaian, Soltani,* 2009], the important thing at this stage is organizational support through the creation of good career trajectories and opportunities for professional growth.

"The strategic deployment of talent", the fourth component, involves deploying the appropriate personnel to necessary positions at the right time, which allows an organization to effectively implement its strategies and prepare for future challenges and opportunities.

Finally, the fifth component, the "measurement and alignment" of talent management activities, is the most important factor supporting the cycle or process of talent management. The power of this talent management process model lies in its dynamic integration of demand for talent, its identification, discovery and use, and its emphasis on bringing personnel potential into line with the overall strategy of an organization [*Cheese et al.,* 2008].

Eghbal et al. [*Eghbal et al.,* 2016] developed a model entitled "the management of gifted personnel at talent-centered universities". The authors identified two components in this process: the attraction and retention of talent, and state that after the discovery of talent, the two aforementioned components are the most important aspects of talent management. In order to deploy talent, which was discovered using reliable indicators, to accomplish organizational goals, measures must be taken to retain talented individuals by keeping employee turnover rates low.

Theoretical developments and empirical research suggest that the performance of faculty members is directly tied to talent management process at a university. Therefore, in our research, faculty members' perception of university management will be investigated. We assume that other variables (in particular, organizational justice) can be placed in chains of causes and effects between independent and dependent variables and influence the results of research.

Neal McNabb [*McNabb,* 2009] coined the term "organizational justice" to describe the relationship between an employee and a system of sanctions and incentives at an organization, and to study its role in a working environment. In fact, the term "perceived organizational justice" describes the direct contribution of the role of justice as an element of this work environment. How employees feel they are treated at work influences other performance variables. In general, perceived organizational justice includes components that distinguish it from actual organizational justice, namely distributive justice, procedural justice and interactional justice, each of which influences the behaviors and performance of employees [*McDowall, Fletcher,* 2004]. Several studies on justice at organizations have traditionally focused on the distribution of work-related pay or bonuses according to the theory of equity in social exchange [*Adams,* 1963].

"Distributive justice" refers to perceived justice of outputs and outcomes that people receive. Of course, distributive justice is not only limited to fair pay but also an extensive collection of organizational outcomes such as promotions, rewards, work plans, benefits and performance evaluations. Poor behavior by employees must entail a fair punishment [*Lambert,* 2003].

"Procedural justice" refers to fair interpersonal relationships related to organizational procedures [*McDowall, Fletcher,* 2004]. Studies show that procedures become fair when used consistently without considering individual attributes or personal privileges, and procedures are considered fair when they are based on accurate information and by considering the interests of all participating organizational units along with the adherence to ethical criteria and norms [*Lambert,* 2003].

"Interactional justice" concerns fairness in interpersonal interactions and is focused on the individual dimension of organizational activities, particularly management behaviors and communication with employees. Interactional justice envisages honesty, sympathy and respect in communication and the justifications for decisions taken at an organization [*McDowall, Fletcher,* 2004].

The theory of perceived organizational justice states that honesty and fairness are considered the most critical factors in a work environment, these factors are a fundamental and necessary basis for the effectiveness of organizational processes. Employee perception of equality and sincerity in their treatment is an important element that influences other work-related variables. Therefore, the vital significance of organizational justice is difficult to overstate because an organization's survival and prosperity depend on it [*Lambert,* 2003].

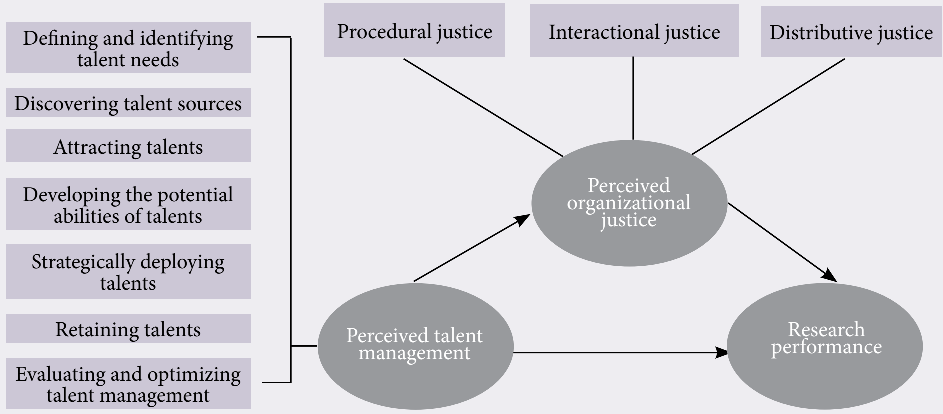
The establishment of perceived organizational justice can lead to an improved work environment and increased confidence in an organization. For this reason, universities, as have other organizations have, have relied on organizational justice and its outcomes to prevent internal and environmental negative factors [*Avital, Collopy,* 2001].

Research performance is also considered one of the fundamental dimensions of university and faculty members' performance and is affected by the faculty members' perception of talent management. The university staff's perception of organizational justice can influence indicators of educational and teaching activity, which further confirms the relevance of studying these processes and ways to improve them.

Therefore, these issues pushed us to investigate the effect of perceived talent management on the research performance of universities' faculty members, which is the main asset of any university. At the same time, we consider the mediating role of perceived organizational justice and will determine the contribution of each related component.

Based on our conceptual research model (Figure 1), faculty members' research productivity is evaluated in line with their views of the talent management process. This process includes such components as defining

Figure 1. **Conceptual research model**



Source: compiled by the authors.

and identifying talent needs, the search for talent, attracting talent, developing talent potential, strategically deploying talent, retaining talent, evaluating employees' activity and the selection of optimal positions for talent. This analysis directly or indirectly touches upon perceived organizational justice, including its distributive, procedural and interactional aspects.

In order to design the conceptual research model, the talent management process model of Cheese, Thomas, Craig [*Cheese et al.,* 2008; *Eghbal et al.,* 2016] and the perceived organizational justice model [*Niehoff, Moorman,* 1993] were used (see Figure 1).

A series of studies [*Lambert,* 2003; *Jiang, Iles,* 2011; *Gelens et al.,* 2014; *Kagwiria,* 2013; *Salehzadeh, Labaf,* 2011] by various methods came to a similar conclusion about the enormous effect talent management has on individual and group productivity, using perceived organizational justice as a key mediating factor. Varying employee performance depends on the effectiveness of talent management processes and their perceptions of organizational justice.

Methodology

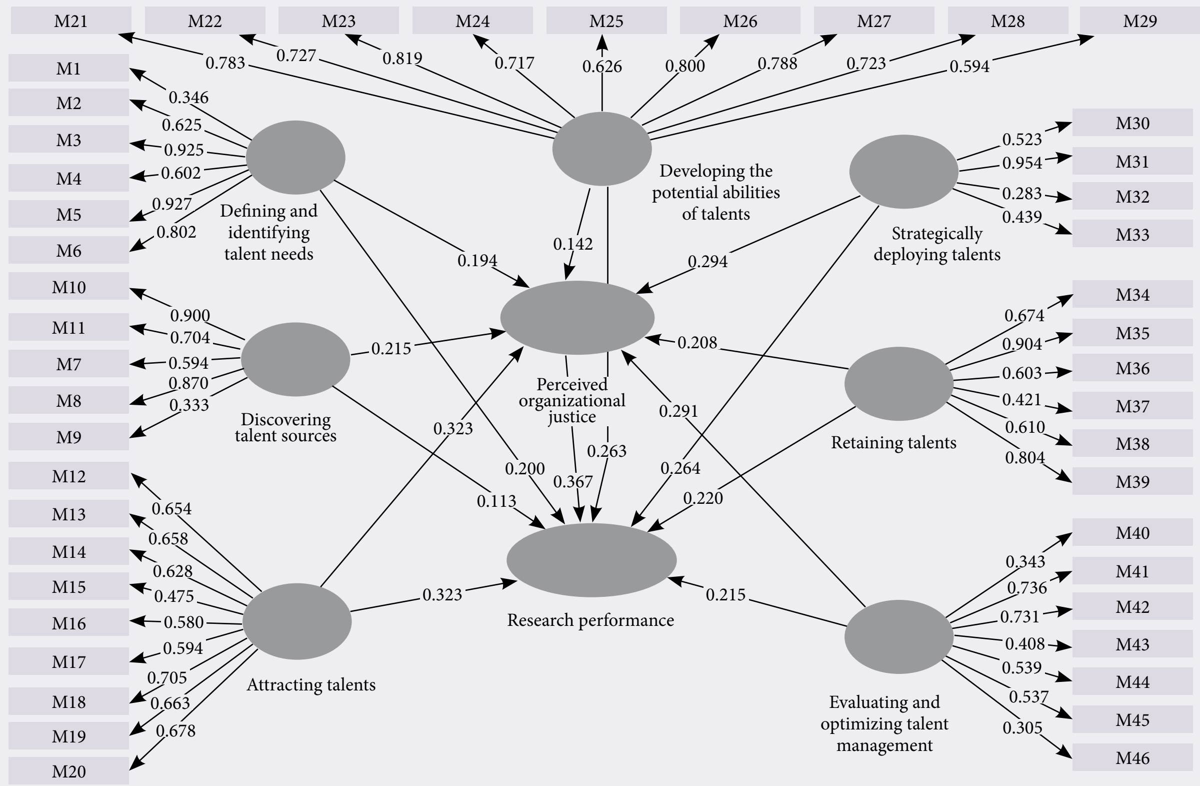
The present research is a correlational-descriptive study and its modeling is based on structural equation modeling. The statistical population of this research consists of the faculty members of selected public universities of Isfahan who were employed during the years 2010–2015. The sample encompasses the University of Isfahan (UI), Isfahan University of Medical Sciences (IUMS) and the Isfahan University of Technology (IUT) and the population size was 562 individuals (241 individuals from University of Isfahan, 189 from Isfahan University of Medical Sciences, and 132 from Isfahan University of Technology).

To calculate the final sample size, SPSS Sample Power software was used. Given the research targets, hypotheses and methods used to investigate these hypotheses, the regression model includes a maximim of eight independent variables that influence the dependent variable. Validity criteria include an error rate of 0.05, a power higher than 0.80, and an effect size of 0.10. Based on this, the final sample size was calculated to be 130 (56 from University of Isfahan, 44 from Isfahan University of Medical Sciences, and 30 from Isfahan University of Technology), who were selected using stratified random sampling proportional to the sample size.

In order to collect the required data, the faculty members' research performance records were used, which were collated and adjusted based on a point system as part of an annual campaign for the evaluation and promotion of employees. The following were taken into consideration: monographs, articles published in current journals, papers presented at conferences, dissertations, scientific discoveries, patents and innovations, projects undertaken within and outside the university, and works of art. An analysis of employees' views of talent management was conducted using Eghbal et al.'s 46-question questionnaire [*Eghbal et al.,* 2016] based on Cheese et al.'s model [*Cheese et al.,* 2008] with seven dimensions (defining and identifying talent needs, searching for talent, attracting talent, developing employee potential, strategically deploying talent, retaining talent, and optimizing talent management activities). In order to measure perceived organizational justice, Niehoff and Moorman's 21-question survey was used [*Niehoff, Moorman,* 1993] with the three dimensions of perceived organizational justice (distributive justice, procedural justice and interactional justice). Measurements were carried out with a 5-point Likert Scale (Strongly agree = 5, agree = 4, somewhat agree = 3, disagree = 2 and strongly disagree = 1). The convergent validity of both questionnaires (AVE) was calculated to be higher than 0.5 and the reliability of both questionnaires using Cronbach's' alpha coefficient was calculated to be higher than 0.75.

For a data analysis at the inferential statistics level, first, the main research hypothesis was examined using variance-based structural equation modeling and a special hypothesis using a one-way ANOVA and Scheffe

Figure 2. **Structural equation modeling of the effect of perceived talent management components on research performance, mediated by organizational justice**



Source: compiled by the authors.

post hoc test with the help of SPSS and Smart PLS software. Testing a hypothesis with this approach helps the researcher treat variables as latent ones and therefore more precisely include measurement errors related to variables and consequently offer more precise estimates.

Research Results and Findings

The mediating role of perceived organizational justice between perceived talent management and research performance is calculated using structural equation modeling and is illustrated in Figure 2 and Tables 1 and 2.

The results of structural equational modeling demonstrates an appropriate fit, in other words, it indicates data support for the research model. Therefore, it can be said that all the indicators are optimal state and demonstrate the appropriateness of structural equation modeling.

The values estimated in Table 2 show that: the components of talent management and perceived organizational justice explain a total of 61% of the total variance of the research performance variable. Given the classification of variables connected with the impact of the determination coefficient, the significance may be considered high. In other words, the components of the variables of talent management and perceived organizational justice can quite reliably explain the variance of research performance.

The indirect effect of the components such as those for attracting talent (0.10), strategically deploying talent (0.11), retaining talent (0.12), and evaluating activity and optimizing talent management (0.08) on research performance is statistically significant ($p \leq 0.05$). Therefore, the variable of perceived organizational justice plays a mediating role in the relationship between these talent management components and the variable

Table 1. **Significance of the indicators for evaluating the overall structural equation model**

Indicator	Value
Goodness of Fit Index (GoF)	0.43
Standardized Root Mean Square Residual (SRMR)	0.07
Normed Fit Index (NFI)	0.91

Source: compiled by the authors.

Table 2. **Estimate of total, direct and indirect effects of the components of perceived talent management and organizational justice on research performance**

Independent variable	Mediator	Dependent variable	The coefficient of determination	Estimate					
				Total		Direct		Indirect	
				Effect	p-value	Effect	p-value	Effect	p-value
Defining and identifying talent needs	Perceived organizational justice	Research performance	0.61	0.23	0.012	0.20	0.015	0.03	0.634
Discovering talent sources				0.14	0.038	0.11	0.050	0.03	0.635
Attracting talents				0.42	0.001	0.32	0.001	0.10	0.032
Developing the potential abilities of talents				0.28	0.001	0.26	0.002	0.02	0.723
Strategically deploying talents				0.37	0.001	0.26	0.003	0.11	0.028
Retaining talents				0.34	0.001	0.22	0.010	0.12	0.020
Evaluating and optimizing talent management				0.30	0.001	0.21	0.012	0.08	0.049
Perceived organizational justice	—			0.37	0.001	0.37	0.001	—	—

Source: compiled by the authors.

of research performance. Taking into consideration the statistical significance of these components for faculty members' research productivity, the mediation of perceived organizational justice is estimated to be insignificant. The values of the indirect coefficients show the direct and weak mediation of organizational justice in the relationship between these components and the variable of research performance in the statistical population of the research. The indirect effect of the other components of perceived talent management, identifying and defining talent needs (0.03), discovering talent sources (0.03), and developing staff potential (0.02) on research performance is not statistically significant ($p > 0.05$). Therefore, the variable of perceived organizational justice in the relationship between these components and research performance does not play a mediating role. In other words, the weak indirect effect of these components on research performance in the statistical sample is estimated to be caused by a sampling mistake or an error, and cannot be generalized to the statistical population of the research with a confidence of 95%.

Hypothesis (1)*: there is significant variety in perceived talent management among the selected universities.*

To investigate the hypothesis above, a one-way analysis of variance was used, the results of the test are reported in Table 3.

The values estimated in Table 3 show that the mean values of perceived talent management and the component of developing staff potential demonstrate that there are significant differences at the three universities of Isfahan (05/0 ≥ Sig).

In other words, the mean at Isfahan University of Medical Sciences is the highest and at University of Isfahan it is the lowest. Regarding other components of perceived talent management, there are no significant differences among the universities (sig > 0.05).

In order to evaluate the difference between the mean values of perceived talent management and the components of developing staff potential, Scheffe's test was used. The test results are reported in Table 4.

The results of Scheffe's test demonstrate the preponderance of the mean values of perceived talent management among faculty members at the Isfahan University of Medical Sciences in comparison with the University of Isfahan and the Isfahan University of Technology. Also, the mean components of developing staff potential among faculty members of the Isfahan University of Medical Sciences is higher than at the other universities.

Hypothesis (2): *there are significant differences in perceived organizational justice among the selected universities*

To investigate the above hypothesis, a one-way analysis of variance was used, the results of the test are reported in Table 5.

The results of one way ANOVA test (f) in Table 5 show that there are no significant differences in the evaluation of organizational justice and its components among the selected universities (sig > 0.05). This allows us to state that the hypothesis that there are notable differences in the perceptions of instructors at different universities concerning organizational justice and its components was not confirmed.

Hypothesis (3): *there are significant differences in research performance indicators among the selected universities.*

To investigate this hypothesis, a one-way analysis of variance was used, the results of the test are reported in Table 6.

Table 3. **Estimated one-way ANOVA to compare perceived talent management**

Variable	University	Mean	Standard deviation	F-statistics	Significance level (Sig)
Perceived talent management	UI	2.77	0.50	4.74	0.012
	IUT	2.91	0.44		
	IUMS	3.04	0.33		
Defining and identifying talent needs	UI	3.37	0.67	0.45	0.638
	IUT	3.41	0.68		
	IUMS	3.50	0.69		
Discovering talent sources	UI	2.72	0.57	2/58	0/083
	IUT	2.85	0.69		
	IUMS	3.05	0.84		
Attracting talents	UI	3.00	0.69	2.78	0.066
	IUT	3.11	0.69		
	IUMS	3.35	0.86		
Developing the potential abilities of talents	UI	2.25	0.72	35.59	0.001
	IUT	2.53	0.67		
	IUMS	3.03	0.21		
Strategically deploying talents	UI	2.85	0.65	0.33	0.718
	IUT	2.96	0.67		
	IUMS	2.88	0.51		
Retaining talents	UI	2.50	0.56	1.61	0.203
	IUT	2.63	0.52		
	IUMS	2.40	0.52		
Evaluating and optimizing talent management	UI	2.88	0.36	0.76	0.471
	IUT	2.95	0.35		
	IUMS	2.83	0.40		

Source: compiled by the authors.

The results of the one-way analysis of variance in Table 6 indicates that there are no significant differences between the research performance of faculty members at the selected universities (sig > 0.05).

Conclusion

Given the fit of the conceptual research model, first, we assumed that the components of the talent management process directly or via perceived organizational justice affected the research performance of the faculty members at the selected public universities of Isfahan. After the analyses were performed, a model was built for measuring the effect of talent management and perceived organizational justice on research performance. The evaluation indicators of the overall structural equation model in general demonstrates empirical support for the theoretical research model. In other words, the data fit the model and the indicators show the appropriateness of the structural equation modelling. The components of talent management and perceived organizational justice explain a total of 61% of the variance in research performance, a quite high figure considering the extent of the coefficient's influence. In other words, the components of talent management and perceived organizational justice can mostly explain the variance in research performance.

The acquired data allow one to evaluate the indirect effect of the components of retaining talent (0.12), strategically deploying talent (0.11), attracting talent (0.10), and talent management and its optimization (0.08) on the research performance of faculty members, which is estimated to be average. Therefore, it can be said that the improvement of these components can lead to increased perceived organizational justice

Table 4. **Scheffe's test to compare the mean estimates of perceived talent management**

Variable	University	Difference in averages	Significance level (Sig)
Perceived talent management	UI	-0.14	0.402
	IUT	-0.26	0.014
	IUMS	-0.12	0.529
Developing the potential abilities of talents	UI	-0.27	0.136
	IUT	-0.78	0.001
	IUMS	0.50	0.003

Source: compiled by the authors.

Table 5. **Results of one-way analysis of variance to compare mean perceived organizational justice among universities**

Variable	University	Mean	Standard deviation	F-statistics	Significance level (Sig)
Perceived organizational justice	UI	2.82	0.42	0.28	0.758
	IUT	2.89	0.43		
	IUMS	2.82	0.42		
Distributive justice	UI	2.42	0.56	0.38	0.668
	IUT	2.51	0.60		
	IUMS	2.39	0.62		
Procedural justice	UI	2.80	0.43	0.13	0.875
	IUT	2.85	0.45		
	IUMS	2.82	0.44		
Interactional justice	UI	3.07	0.51	0.25	0.782
	IUT	3.13	0.51		
	IUMS	3.05	0.46		

Source: compiled by the authors.

and, consequently, improved research performance. Meanwhile the weakening of these components can lead to a decline in perceived organizational justice and, consequently, decreased or weakened research performance.

It can be concluded that faculty members' perceived organizational justice is influenced by their perception of the talent management processes at their universities. In order to make faculty members feel that they are working at a university founded upon principles of justice, it is necessary to pay attention to the components of talent management, while the research performance of faculty members is influenced by talent management and perceived organization justice. These results are in line with the studies of [*Lambert,* 2003; *Jiang, Iles,* 2011; *Gelens et al.,* 2014; *Kagwiria,* 2013; *Salehzadeh, Labaf,* 2011].

The higher the impact factors, the higher too is the influence of the relevant component. Therefore, according to Table 4, the impact of the component of retaining talent (0.12) on research performance as mediated by perceived organizational justice is the highest. Given that retaining talent means keeping employee turnover rates low, which is the top priority at modern organizations, it therefore is recommended that university management boards provide: the necessary job security for their faculty members, fair salaries and bonuses, opportunities for career development, sufficient facilities and resources for employees' professional activities, and opportunities for staff to participate in international conferences by ensuring the necessary resources are in place.

The second most important component of research performance with the mediation of perceived organizational justice is the component of strategically deploying talent, with an impact factor of (0.11). Given that strategically deploying talent involves being able to select the right people for the right jobs at the right time, this allows an organization to effectively implement its strategies and prepare for future challenges and opportunities. University authorities are therefore recommended to ensure that employees' opportunities are in line with their job description, interests, knowledge and skills, and when deploying faculty members for educational or administrative tasks, management should consider the principle of competency.

The third component is attracting talent with an impact factor of (0.10). Given that attracting talent means the selection and employment of suitable individuals based on appropriate indicators, university authorities are recommended to pay attention to the communication skills of applicants, including their English proficiency, their ability to use information technologies. Management should also consider their skills and adaptability, including the ability to quickly learn and master new skills, their personality traits (decisiveness, observational skills, willingness to take risks, etc.) and their behavioral characteristics (whether they are hard workers, patient, and conscientious, etc.), and whether they are law-abiding. Finally, the specialized knowledge on individuals must be evaluated. All of the aforementioned traits of potential employees can be discovered during structured interviews with relevant experts. Furthermore,

Table 6. **Results of one-way analysis of variance to compare the average research performance among universities**

Variable	University	Mean	Standard deviation	F-statistics	Significance level (Sig)
Research performance	UI	5.30	0.88	0.96	0.390
	IUT	5.07	0.96		
	IUMS	5.42	1.20		

Source: compiled by the authors.

in order to bring in the best talent, it is necessary to thoroughly analyze the professional background of the applicants based on pre-determined criteria.

The fourth component influencing research performance through perceived organizational justice is the component of the evaluation and optimization of talent management with an impact factor of (0.08). Given the significance of this component of talent management activities, university authorities are recommended to design a comprehensive evaluation system at the university that provides information about the strong and weak points of all parts of the talent management process (identification, attraction, deployment, development and retention).

Since the components of developing talent, discovering talent sources, and identifying and defining talent needs directly influence research performance, university management must ensure the improvement of education, research, communication, technology, and professional ethics, abd the development of skills. Management should also provide incentives for faculty members to study outside the university, they should subsidize participation in foreign academic programs. In order to develop talent, universities must have a written program of methodological recommendations though which faculty members at the mastery level could train individuals to replace them when they retire. With such a system in place, the information and experience of these faculty members would not be lost.

The search for talent involves the use of special methods for discovering the most gifted individuals within and outside of the university for their subsequent employment. Awareness and the formulation of a survey for talent begins with a clear understanding of the available specialists and the competencies that would be needed in the medium term (over the next five years). Then indicators should be determined for the personal and behavioral characteristics, the field of specialty, professional skills and key competencies of those applicants for teaching positions in order to select those individuals who will meet the university's needs to the greatest extent possible.

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Relationships between Lecturer Performance, Organizational Culture, Leadership, and Achievement Motivation

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Abstract

This research is aimed at finding the effects of: 1) organizational culture on performance, 2) leadership on performance; 3) achievement motivation on performance; 4) organizational culture on achievement motivation; 5) leadership on achievement motivation. This research used a survey method with a causal approach. There were 255 lecturers selected from initial population of 706 individuals based on a simple random technique as the sample. This research was conducted using questionnaires given to lecturers in Jambi University. The validity test was conducted using the Cronbach's alpha.

The results showed that: first, there was a direct effect of organizational culture on performance; second, there was a direct effect of leadership on performance; third, there was a direct effect of achievement motivation on performance; fourth, there was a direct effect of organizational culture on achievement motivation; fifth, there was a direct effect of leadership on achievement motivation. The implication of this research is that the effort to improve lecturer performance can be made by improving the organizational culture, leadership, and achievement motivation.

Keywords:
performance;
organizational culture;
leadership;
achievement motivation.

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Lecturer performance is a key aspect of the quality of a university's educational program. Good performance by a single lecturer can have a positive impact on the university as a whole, therefore the university can arrange an optimal work program in order to improve the quality of the university. There are many factors influencing lecturer performance, one of which is the number of students. The higher the number of students, the higher the teaching load on a lecturer, which in turn can affect his/her performance at the university.

Jambi University was established on April 1, 1969 and initially consisted of the Faculty of Economics, Faculty of Law, the Faculty of Agriculture, and the Faculty of Animal Husbandry[1]. Later, in 1982, there a Decree of the President of the Republic of Indonesia was issued that stipulated that Jambi University would consist of the Faculty of Teacher Training and Education, the Faculty of Economics, the Faculty of Law, the Faculty of Agriculture, and the Faculty of Animal Husbandry[2]. According to University's Bureau for Administration and Finance as of 2012, Jambi University employed 717 lecturers at the 5 faculties, as follows: 205 lecturers in the Faculty of Teacher Training and Education (FKIP), 129 in the Faculty of Economics (FE), 103 in the Faculty of Law (FH), 170 in the Faculty of Agriculture (FAPERTA), and 110 in the Facutly of Animal Husbandry (FAPET) [Jambi University, 2012]. However, the number of lecturers is still lower than the number of the students at Jambi University, there are currently 28,000 students, with a teacher to student ratio of 1:39. The ideal ratio of the number of lecturers and the number of students is 1:20.

Daft [*Daft,* 2003, p. 22] defines performance as, in a broader definition, an organization's ability to achieve its goals, accomplish its tasks and implement its strategies. An organization should have clarity, both in its objectives and strategies. There are four ways to achieve effective performance at an organization [*Robbins,* 1990, p. 77]: 1) *goal attainment*, how an organization is able to attain its final goals that have been set down its development program, 2) the *system*, how an organization is able to obtain the necessary resources, 3) *strategic constituencies,* how an organization can bring its targets into line with the objectives of *strategic constituencies*, 4) *competing values*, an effective organization's ability to compete within the broader environment.

The individual outcomes at an organization, which are understood as performance and organizational commitment are affected by several factors [*Colquitt et al.,* 2009, p. 8]: 1) job satisfaction; 2) stress levels; 3) motivation; 4) trust, justice, and ethics; and 5) learning and decision making. Performance is a valuable asset and entails the set of behavioral characteristics of possessed by an employee, which has both positive and negative consequences for the achievement of an organization's goals [*Ibid.,* p. 37].

A lecturer is obliged to guide his/her students in the interests of state education, in other words, a lecturer must have certain professional skills [*Hamalik,* 1989, p. 123]. As a professional, a lecturer at Jambi University has the following duties: 1) to help implement both the academic and non-academic programs of the university, (2) to use all available means to provide high-quality teaching and education, (3) have to preserve and develop knowledge by implementing the three pillars of tertiary education (*tridharma perguruan tinggi*): education and teaching, research, and community service [Jambi University, 2009, p. 11].

Jambi University is among those organizations at which lecturer performance plays an important role in improving the quality of its graduates. The improvement in lecturer performance demands more time and effort from the faculty and university as a whole in order to accelerate the achievement of the university's visions and mission. Based on the definition above, it can be stated that lecturer performance at Jambi University involves the lecturers' ability to conduct their duties and functions in line with the university's organizational goals, which are expressed in qualitative and quantitative indicators including professional skills, working knowledge, creativity, cooperation within a team, subordination, initiative, and individual characteristics.

Furthermore, the organizational culture consists of a set of values that are shared by all employees, which provide the members of the organization with guarantees and help. The reproduction of this culture is attained through the dissemination of social knowledge among the organization, which is based on the rules, norms, values, attitude and behavior of the employees. "*A shared social knowledge within an organization regarding the rules, norms, and values shapes the attitude and behaviors of its employees*" [*Colquitt et al.,* 2009, p. 546].

Diana C. Pheysey [*Pheysey,* 1993, p. 3] defines culture as a way of encouraging habits among a large number of people. Culture opens one to changes. Therefore, Diana Pheysey defines culture as follows: "*A culture is thus a way of seeing what is common to many people. Culture itself is subject to [constant] transformation*". In other words, Diana C. Pheysey wanted to say that culture is usually used as a source of guidance by all of its proponents and it also serves as a source of change. Thus, the organizational culture at Jambi University is not constant or eternal, but can change at anytime, if such a change is supported by its members.

The organizational culture at Jambi University contains both formal and informal components, values that govern the behavior of both individuals and groups. Interactions between individuals and groups

[1] Decree of the Minister of Education No. 25 of 1963.

[2] Decree of President of the Republic of Indonesia No. 41 of 1982.

at the organization are controlled by the values and norms of the university. It is necessary to have control mechanisms in place, which have been mutually agreed upon and accepted in order to ensure that individual behavior does not deviate from the aforementioned values and norms. Based on the description above, organizational culture can be defined as a set of values that is accepted by the members of an organization as a guiding principle for action. Manifestations of this organizational culture include tolerance, respect for authority, integrity, loyalty, cooperation, mutual respect, confidence, attention, sacrifice, transparency, and dedication to one's work.

Leadership is understood as a dynamic process tied to one's ability to influence others. The source of this influence may be formally proscribed or informal, carried out on the basis of one's relationships. Strong leadership and management are needed to improve lecturer performance at Jambi University. Hersey and Blanchard [*Hersey, Blanchard,* 1985, p. 86] define leadership as a process in which authority is exercised in order to achieve a goal in a certain situation. A leader needs authority, but this does not mean more power is always better. Leadership is comprised of five types of authority [*French, Raven,* 1959; *Yukl,* 2011, p. 190]: (1) *Incentive power*, a reward is given on the basis of a person's ability as determined by the leader; (2) *Coercive power*, the imposition of a leader's will on a person, who follows the commands to avoid punishment; (3) *Legitimate power*, authority, which is set down in law or regulations and entitles the one with it to issue binding orders; (4) *Expert power*, the authority to use one's expert knowledge to complete a job; (5) *Charismatic power*, the power of a person who is admired by the others due to his/her nature and appeal.

Emmy and Taty [*Emmy, Taty,* 1994, p. 110] state that leadership is task-oriented and focused on observing the interests of one's employees. There are four leadership strategies [*Robbins et al.,* 2013]: (1) the leader who directs his or her followers, lets them know what should be expected from him or her, determines the schedule and gives specific guidelines for the completion of tasks, (2) a charming, friendly leader who cares about the needs of his followers, (3) an involved leader, who is open to communication with his or her subordinates and discusses goals before making a decision, (4) a leader, focused on achievements, who sets challenging goals and expects his or her subordinates to perform at their highest level.

Gibson, Donelly and Ivancevich [*Gibson et al.,* 1996, p. 3] define leadership as the ability to influence others and imbue them with a sense enthusiasm in striving to achieve the set goals. This definition stipulates a change of the subject itself, which influences others. A similar opinion is also expressed by Matondang [*Matondang,* 2008, p. 5] who defines leadership as a process of influencing other people to do or not do a certain task. The definition by Matondang stipulates a university leader's attitudes and patterns of behavior as well as the use of one's authority to influence other people in the achievement of certain goals.

Based on the definitions above, it can be stated that leadership at Jambi University includes the behavior and actions, which are reflected in the changes of the person who influences others, both individuals and groups, to achieve organizational goals. On the surface this process is expressed in quick decision making, the organization of work, the provision of guidance, encouragement, responsibility and attention, the correction of mistakes, the encouragement of cooperation and the development of policy.

Similarly, the motivation a lecturer to achieve his/her goals lies in his/her ability to motivate him-/herself in overcoming the challenges and obstacles that lie in the way of achieving said goals. Danim and Suparno [*Danim, Suparno,* 2008, p. 33] focus on three needs, they are: *the needs for achievement*, *affiliation,* and *power.* The first encompasses Jambi Univerity employees' internal motivation to perform their duties by improving their teaching performance in order to bring the organization closer to achieving its goals. Such motivation is considered a condition that allows lecturers to bring their behavior into line with organizational tasks. Furthermore, another approach was expressed by Siagian [*Siagian,* 1989, p. 128] in which professional motivation includes a whole number of factors, which turn workers into dedicated employees who are willing to work sincerely for the sake of achieving an organization's goals in the most efficient and economical manner possible.

Therefore, lecturers' motivation to achieve at Jambi University includes the individual's motivation to think, act, work, and overcome any obstacle when fulfilling one's duties. Indicators of this motivation include hopes for success, fear of failure, one's competitive spirit and diligence.

This study was conducted to order to determine whether the organizational culture, leadership and motivation to achieve have a direct effect on lecturer performance at Jambi University.

Research Methodology

This research used the survey method by distributing questionnaires to the target respondents. This target population is comprised of lecturers at Jambi University. The sample included 706 lecturers at Jambi University, who had been civil servants for at least three years. Data was gathered using the path analysis method, while the sample was collected by using probability sampling. The sample was collected by providing every individual in the population an equal chance of being included in the sample. The data were collected using questionnaires as the research instrument, these questionnaires were developed based on a conceptual and operational definition, and a matrix analysis of each research variable.

Table 1. **Path coefficients of the first structural model (dependent variable — lecturer performance)**

Model	Unstandardized coefficients		Standardized coefficients	t-test	Significance level (Sig)
	B-coefficient	Standard error	Beta-coefficient		
(Constant)	2.800	7.418		0.377	0.706
Organizational culture X_1	0.223	0.078	0.222	2.855	0.005
Leadership X_2	0.379	0.081	0.368	4.701	0.000
Achievement motivation X_3	0.260	0.052	0.255	5.039	0.000

Source: calculated by the authors.

The subject of analysis is the impact of organizational culture, leadership and individual motivation to achieve on the teaching performance of lecturers at Jambi University. A validation test showed that the significance of each research variable allows for further statistical tests. The research hypothesis was tested by calculating the path coefficients based on the proposed hypothesis, they were P_{y1}, $P_{y2,}$ $P_{y3,}$ $P_{y4,}$ P_{31} and $P_{32.}$ Path coefficient calculations were conducted using SPSS software.

Results

The results of the Lilliefors Test, a normality test, allowed us to form the following statistical hypotheses:

H_0: the population data has an estimation error with normal distribution

H_1: the population data has an estimation error with unusual distribution.

The provision in this test is that if the statistic of L_{count} (L_0) < L_{table} (α =0.05), then the data error will have a normal distribution. Otherwise, if L_{count} (L_0) > L_{table} (α =0.05), then the data will have a non-normal distribution. (1) Initially, a normality test of the error score of lecturer performance on organizational culture (X_4 on X_1) was conducted. The *Liliefors* statistical calculation obtained the following result: L_{count} = 0.0527. It is lower than L_{table} (n = 225; α = 0.05) = 0.0555. Thus, it can be said that the distribution of the estimation error of lecturer performance (X_4) on organizational culture (X_1) has resulted from a normally distributed population. (2) Next, a normality test of the error score of lecturer performance on leadership (X_4 on X_2) was conducted. The *Liliefors* statistical calculation obtained L_{count} = 0.0534. It is lower than L_{table} (n = 225; α = 0.05) = 0.0555. Thus, it can be said that the distribution of estimation error of lecturer performance (X_4) on leadership (X_2) has resulted from a normally distributed population. (3) Then a normality test of the error score of lecturer performance on achievement motivation (X_4 on X_3) was carried out. The *Liliefors* statistical calculation obtained L_{count} = 0.0522. It is lower than L_{table} (n = 225; α = 0.05) = 0.0555. Therefore, it can be said that the distribution of the estimation error of lecturer performance (X_4) on achievement motivation (X_3) is the result of a normally distributed population. Furthermore, the results of the calculation of Substructure 1 of the effects of $x_{1,}$ x_2 and x_3 on x_4 can be seen in the Table 1:

Based on the information presented in Table 1 above, the standardized value of the regression coefficient (Beta) for Organizational Culture (X_1) on Lecturer Performance (X_4) P_{y1} is 0.222; for Leadership (X_2) on Lecturer Performance (X_4) P_{y2} is 0.368; and for Achievement Motivation (X_3) on Lecturer Performance (X_4) P_{y3} is 0.255. Thus, the formed path coefficients in the first equation model are as follows:

P_{y1} = 0.222
P_{y2} = 0,368
P_{y3} = 0.255

The results of the calculation of Substructure 1 of the effects of $x_{1,}$ x_2 and x_3 can be seen in Table 2 below.

Based on the results presented in Table 2, the standardized value of regression coefficient (Beta) for Organizational Culture (X_1) on Achievement Motivation (X_3) P_{31} is 0.255; and for Leadership (X_2) on Achievement Motivation (X_3) P_{32} is 0.303. Thus, the formed path coefficients in the second equation model are as follows:

Table 2. **Regression coefficients of the second structural equation (dependent variable — achievement motivation)**

Model	Unstandardized coefficients		Standardized coefficients	t-test	Significance level (Sig)
	B-coefficient	Standard error	Beta-coefficient		
(Constant)	41.377	8.654		4.781	0.000
Organizational culture X_1	0.251	0.094	0.255	2.673	0.008
Leadership X_2	0.306	0.096	0.303	3.178	0.002

Source: calculated by the authors.

Table 3. **Illustration of the calculation of path coefficients**

Path	Path coefficient	t_{count}	t_{table} (a=0.05)	t_{table} (a=0.01)	Information
$X_1 \rightarrow X_4$	$p_{y1} = 0.222$	2.855	1 .6510	2 .3414	Very significant
$X_2 \rightarrow X_4$	$p_{y2} = 0.368$	4.701	1 .6510	2 .3414	Very significant
$X_3 \rightarrow X_4$	$p_{y3} = 0.255$	5.039	1 .6510	2 .3414	Very significant
$X_1 \rightarrow X_3$	$p_{31} = 0.524$	2.673	1 .6510	2 .3414	Very significant
$X_2 \rightarrow X_3$	$p_{32} = 0.303$	3.178	1 .6510	2 .3414	Very significant

Source: calculated by the authors.

P_{31} = 0.255
P_{32} = 0.303

The results of the calculaltion of the path coefficients of the exogenous variables on the endogenous variables are illustrated in Table 3.

The calculation for the *first* hypothesis obtained t_{count} = 2.855, which is higher than $t_{table\ (0.01)}$ = 2,3414. Since the $t_{count} > t_{table}$ or 2.855 > 2.3414, then H_0 is rejected. Thus, it can be concluded that organizational culture (X_1) directly affects lecturer performance (X_4). The calculation for the *second* hypothesis obtained t_{count} = 4.701, which is higher than $t_{table\ (0.01)}$ = 2.3414. Since the $t_{count} > t_{table}$ or 4.701 > 2.3414, then H_0 is rejected. Thus, it can be concluded that leadership (X_2) directly impacts lecturer performance (X_4). The calculation for the *third* hypothesis obtained t_{count} = 5.039, which is higher than $t_{table\ (0.01)}$ = 2.3414. Since the $t_{count} > t_{table}$ or 5.039 > 2.3414, then H_0 is rejected. Thus, it can be concluded that achievement motivation (X_3) has a direct impact on lecturer performance (X_4). The calculation for the *fourth* hypothesis obtained t_{count} = 2.673, which is higher than $t_{table\ (0.01)}$ = 2.3414. Since the $t_{count} > t_{table}$ or 2.673 > 2.3414, then H_0 is rejected. Thus, it can be concluded that organizational culture (X_1) directly influences achievement motivation (X_3). The calculation for the *fifth* hypothesis obtained t_{count} = 3.178, which is higher than $t_{table\ (0.01)}$ = 2.3414. Since the $t_{count} > t_{table}$ or 3.178 > 2.3414, then H_0 is rejected. Thus, it can be concluded that leadership (X_2) has a direct effect on achievement motivation (X_3).

Discussion

The findings showed that organizational culture has a direct effect on lecturer performance at Jambi University. The findings of this research suggest that efforts made to improve the quality of tertiary education should begin in human resources (HR) departments. The mission of Jambi University, stipulates "the provision of an education by qualified personnel and a healthy academic climate, the conduct of research that supports national development and encourages the achievement of the strategic goals of Jambi University to be an advanced university in the national education system".

According to Indonesian legislation, specifically law number 14 of 2005 concerning teacher and lecturers[3], the profession of lecturer and teacher is a special field guided by certain principles: 1) one should be distinguished by one's talent, interest, and idealism; 2) demonstrate a commitment to improving the quality of education, decency, conscientiousness, and noble character; 3) possess academic qualifications and an educational background suited to one's position; 4) be responsible for the implementation of professional duty; 5) obtain income based on one's achievements; 6) be given the opportunity to develop his/her qualifications through life-long learning; 7) possess legal guarantees for doing one's professional duty; 8) belong to a professional organization that is authorized to regulate issues related to the professional responsibilities of a lecturer.

The findings of this research are in line with the integrative model of the organizational approach of Colquitt, Lepine and Wesson [*Colquitt et al.,* 2009, p. 8], in which performance within an organization is closely related to an employee's commitment to basic corporate targets, namely organizational culture, leadership, and the motivation to achieve. Leadership is very important in order to understand how people are able to exert their influence within an organization, while subjects have the ability to influence one another [*Mitzberg,* 1983; *Pfeffer,* 1992; *Yukl,* 2011, p. 172].

Lecturer performance at Jambi University depends on whether a leader is able to positively influence the lecturers and facilitate their optimal development. Meanwhile, the motivation to achieve finds similar significance, as it has a direct effect on lecturer performance at Jambi University. This motivation is particularly important for employees. Danim and Suparno [*Danim, Suparno,* 2008, p. 33], state that lecturers' social lives are mostly conducted on the campus where they work. A conducive environment will encourage their professional growth through competition with their colleagues. This healthy competition will be a factor in the future development of the individual.

[3] Republic of Indonesia Law on Teachers and Lecturers No. 14/2005.

Our findings are also in line with the theory of the motivation to achieve [*McClelland,* 1988; *Danim, Suparno,* 2008, p. 34], which states that humans need to have achievements, affiliation, and power. These needs can be fulfilled only if the lecturers are given far-reaching opportunities for professional development by the management of Jambi University. The fulfillment of tasks delegated by management not only requires time from employees, but also the relevant infrastructure, an atmosphere of trust and confidence, and appropriate rewards and remunerations.

Organizational culture has a direct effect on the motivation to achieve. The results of the research conducted with Jambi University employees allowed us to empirically confirm the theory proposed by Stephen Robbins [*Robbins et al.,* 2013], which postulates that organizational culture is characterized by ten traits: *individual initiative*, *risk tolerance, governance, integration, administrative support, control, identity, reward, conflict tolerance*, and *communication patterns.* In order to further develop these conclusions, one must study the degree to which the various traits described in Robbins's theory are present and cultivated at Jambi University.

The result of the test on the fifth hypothesis showed that the leadership variable has a direct effect on achievement motivation. Empirically, evidence from the research conducted at Jambi University is in line with the model of organizational behavior [*Colquitt et al.,* 2009, p. 8], in which organizational culture, leadership, and the motivation to achieve become the background for achievement and performance within an organization. In this context, the organization is a university, that is, Jambi University, and how it conducts its daily learning activities within its academic programs. The leader therefore mobilizes the potential of lecturers so that they can reach their goals. Hersey and Blanchard [*Hersey, Blanchard,* 1985, p. 86] argue that leadership is the process of managing one's authority to achieve set goals. Gibson, Donelly and Ivancevich [*Gibson et al.,* 2006, p. 21] suggest that leadership is the ability to influence other people and imbue them with the enthusiasm necessary to accomplish those goals. A university leader, especially at Jambi University, should be in a position to meet the needs of his/her employees, in particular concerning career development, which is possible if lecturers have attained considerable achievements.

Conclusions

Our analysis has allowed us to draw the following conclusions. Organizational culture directly impacts one's motivation to achieve, which is the case for the lecturers at Jambi University. The type of leadership determines the character of this motivation, and effective management leads to increased motivation and enthusiasm. In turn, the motivation to achieve directly impacts lecturer performance: when motivation is higher, the lecturers perform better. Performance also is directly dependent on the organizational culture that is in place, and the example of Jambi University serves to confirm this assertion. Finally, the results of teaching activity are determined by the quality of leadership. If there is effective leadership, then lecturers' work will be similarly effective.

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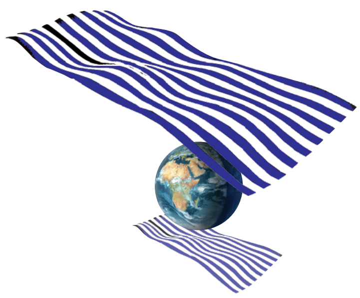

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