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.

Citation: Unger M., Polt W. (2017) The Knowledge Triangle between Research, Education and Innovation – A Conceptual Discussion. *Foresight and STI Governance*, vol. 11, no 2, pp. 10–26.
DOI: 10.17323/2500-2597.2017.2.10.26

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.

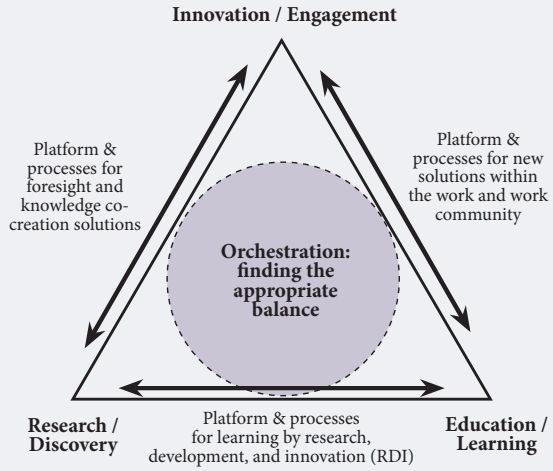
Table 1. **Complementary concepts of innovation system governance**

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].

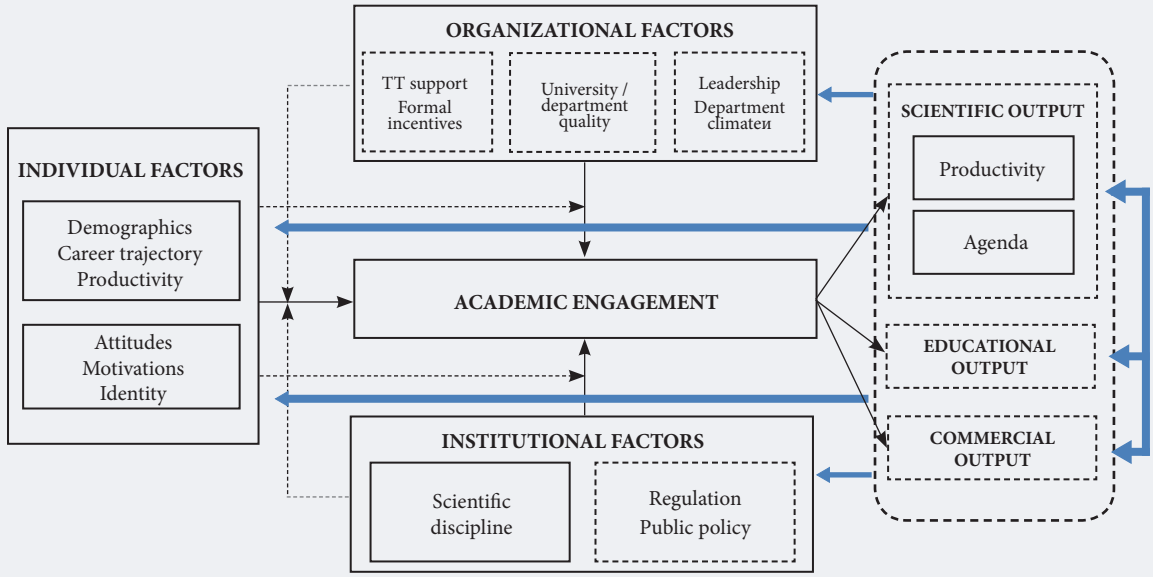
the academic sector to the social and business sectors [OECD, 2013; *Perkmann et al.,* 2012; *Arundel et al.,* 2013; *Mathieu,* 2011]. Some channels are used by third-party actors, such as companies, for the transformation of the products of university research and educational activity into innovations, 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.

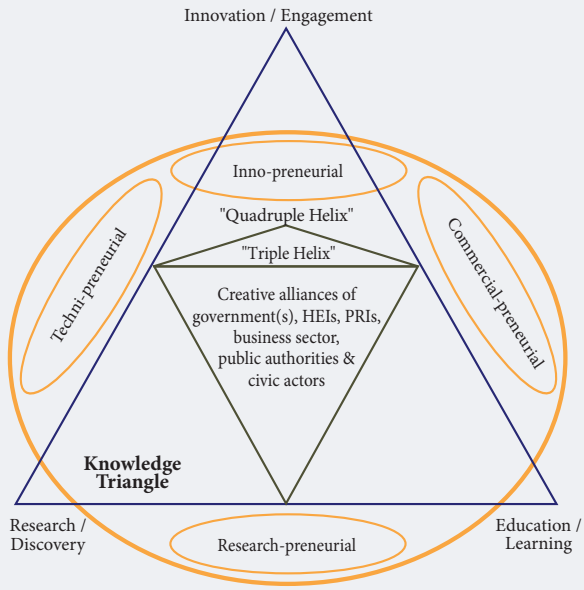
Additionally, HEIs provide direct economic stimuli for regions i) as an employer (of not only academic personnel), ii) by the demand created by its students, iii) by expenditures and investments in the construction of infrastructure [*Musil, Eder,* 2013], iv) by contributing to the "branding" of a region, 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.

References

Aghion P., Dewatripont M., Hoxby C.M., Mas-Colell A., Sapir A. (2009) *The Governance and Performance of Research Universities: Evidence from Europe and the U.S.* (NBER Working Paper № 14851), Cambridge, MA: National Bureau of Economic Research.

Arundel A., Es-Sadki N., Barjak F., Perret P., Samuel O., Lilischkis S. (2013) *Knowledge Transfer Study 2010–2012* (Final Report on behalf of the EC Directorate-General for Research and Innovation), Brussels: European Commission.

Bronstein J., Reihlen M. (2014) Entrepreneurial University Archetypes. A Meta-Synthesis of Case Study Literature. *Industry and Higher Education*, vol. 28, no 4, pp. 245–262.

Council of the European Union (2009) *Conclusion of the Council and of the Representatives of the Governments of the Member States, Meeting within the Council on Developing the Role of Education in a Fully-functioning Knowledge Triangle* (Note 14344/09, 20.10.2009), Brussels: Council of the European Union.

Damsgaard E.F., Thursby M.C. (2013) University entrepreneurship and professor privilege. *Industrial and Corporate Change*, vol. 22, no 1, pp. 183–218.

De Boer H., Jongbloed B., Benneworth P., Cremonini L., Kolster R., Kottmann A., Lemmens-Krug A., Vossensteyn H. (2015) *Performance-based funding and performance agreements in fourteen higher education systems* (Report for the Dutch Ministry of Education, Culture and Science), Twente: University of Twente.

EARTO (2005) *Research and Technology Organisations in the Evolving European Research Area – A Status Report with Policy Recommendations*, Brussels: European Association of Research and Technlogy Organisations.

Edquist C. (1997) *Systems of Innovation: Technologies, Institutions, and Organizations,* London: Pinter.

Etzkowitz H. (1983) Entrepeneurial Scientists and Entrepeneurial Universities in American Academic Science. *Minerva. A Review of Science, Learning and Policy*, vol. 21, no 2–3, pp. 198–233.

Etzkowitz H., Leydesdorff L. (2000) The dynamics of innovation: From national systems and "mode 2" to a triple hélix of university-industry-government relations. Research Policy, vol. 29, no 2, pp. 313–320.

Etzkowitz H., Ranga M., Benner M., Guaranys L., Maculan A.M., Kneller R. (2008) Pathways to the entreprepneurial university: Towards a global convergence. *Science and Public Policy*, vol. 35, no 9, pp. 681–695.

EURAB (2005) *Research and Technology Organisations (RTOs) and ERA* (European Research Advisory Board – Final Report), Brussels: European Commission.

European Commission (2011a) *Connecting Universities to Regional Growth: A Practical Guide*, Brussels: European Commission.

European Commission (2011b) *Supporting growth and jobs – An agenda for the modernisation of Europe's higher education systems* (COM(2011) 567 final, 20.09.2011), Brussels: European Commission.

European Commission (2012) *Guide to Research and Innovation Strategies for Smart Specialisations* (RIS 3), Brussels: European Commission.

European Council (2010) *Cover Note from General Secretariat of the Council to the Delegations* (EUCO 13/10, 17.06.2010), Brussels: European Council.

Foss L., Gibson D.V. (eds.) (2015) *The Entrepreneurial University – Context and Institutional Change*, New York: Routledge.

Goddard J. (2009) *Reinventing the Civic University,* London: NESTA.

Goddard J., Puukka J. (2008) The Engagement of Higher Educational Institutions in Regional Development: An Overview of the Opportunities and Challenges. *Higher Education Management and Policy*, vol. 20, no 2, pp. 11–41.

Gulbrandsen M. (2011) *Research institutes as hybrid organizations: Central challenges to their legitimacy*, Heidelberg; New York; Dordrecht; London: Springer.

Hazelkorn E. (2010) *Teaching, Research and Engagement: Strengthening the Knowledge Triangle* (Paper presented at SIRUS seminar, November 25–26, 2010).

Henke J., Pasternack P., Schmid S. (2015) *Viele Stimmen, kein Kanon – Konzept und Kommunikation der Third Mission von Hochschulen*, Halle: Institut für Hochschulforschung (HoF) an der Martin-Luther-Universität, Halle-Wittenberg.

Hicks D. (2011) Performance-based university research funding systems. *Research Policy*, vol. 41, no 2, pp. 251–261.

Jackson D.J. (2011) *What is an Innovation Ecosystem?* (White Paper), Arlington, VA: US National Science Foundation.

Jaffe A.B. (1986) Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value. *American Economic Review*, vol. 76, no 5, pp. 984–1001.

Karlsson C., Andersson M. (2005) *Company R&D and University R&D — How Are They Related?* (Working Paper prepared for EARSA conference 2005), Available at: http://www-sre.wu-wien.ac.at/ersa/ersaconfs/ersa05/papers/305.pdf, accessed 12.12.2016.

Leydesdorff L. (2012) The Triple Helix, Quadruple Helix, …, and an N-Tuple of Helices: Explanatory Models for Analyzing the Knowledge-Based Economy? *Journal of the Knowledge Economy*, vol. 3, no 1, pp. 25–35.

Lundvall B.-Å. (1992) *National Innovation Systems: Towards a Theory of Innovation and Interactive Learning*, London: Pinter.

Markkula M. (2013) The knowledge triangle: Renewing the university culture. *The Knowledge Triangle: Re-inventing the Future* (eds. P. Lappalainen, M. Markkula), Aalto: Aalto University, pp. 11–32.

Mathieu A. (2011) *University-Industry interactions and knowledge transfer mechanisms: A critical survey* (CEB Working Paper no 11/015), Brussels: Université Libre de Bruxelles.

Mazzucato M. (2013) *The Entrepreneurial State: Debunking Public vs. Private Sector Myths*, London: Anthem Press.

Musil R., Eder J. (2013) *Wien und seine Hochschulen: Regionale Wertschöpfungseffekte der Wiener Hochschulen*, Wien: Verlag der Österreichischen Akademie der Wissenschaften.

Niederl A., Bonaccorsi A., Lepori B., Brandt T., de Filippo D., Schmoch U., Schubert T., Slipersaeter S. (2011) Mapping the European higher education landscape: New insights from the EUMIDA project. *Knowledge, Diversity and Performance in European Higher Education: A Changing Landscape* (ed. A. Bonaccorsi), Cheltenham, UK; Northampton, MA, US: Edward Elgar, pp. 13–46.

OECD (2007) *Higher Education and Regions – Globally Competitive, Locally Engaged*, Paris: OECD.

OECD (2011a) OECD *Innovation Policy Platform. Actor Brief on Public Research Organisations (PROs)*, Paris: OECD.

OECD (2011b) *Public Research Institutions – Mapping Sector Trends*, Paris: OECD.

OECD (2013) *Commercializing Public Research – New Trends and Strategies,* Paris: OECD.

OECD (2014a) *Innovation driven growth in regions: The role of smart specialisation*, Paris: OECD.

OECD (2014b) *Reviews of Innovation Policies: France*, Paris: OECD.

OECD (2014c) *Reviews of Innovation Policy: Netherlands,* Paris: OECD.

OECD (2014d) *Reviews of Innovation Policy: Sweden,* Paris: OECD.

OECD (2015) *Scoping Paper: Higher Education Institutions in the Knowledge Triangle,* Paris: OECD.

OECD (2016) *Reviews of Innovation Policy: Sweden 2016,* Paris: OECD.

Perkmann M., Tartari V., McKelvey M., Autio E., Broström A., D'Este P., Fini R., Geuna A., Grimaldi R., Hughes A., Krabel S., Kitson M., Llerna P., Lissoni F., Salter A., Sobrero M. (2012) Academic en-gagement and commercialisation: A review of literature on university industry relations, *Research Policy*, vol. 42, no 2, pp. 423–442.

Pielke R.A. Jr. (2007) *The honest broker: Making sense of science in policy and politics*, Cambridge: Cambridge University Press.

Polt W., Unger M., Ploder M., Wagner-Schuster D., Bundgard Vad T., Palmquist S., Barslund Fosse H. (2015) *The Leverage Potential of the European Research Area for Austria's Ambition to Become One of the Innovation Leaders in Europe – A Comparative Study of Austria, Sweden and Denmark* (Studie im Auftrag des ERA Council Forum Austria), Vienna: Joanneum Research.

Pruvot E.B., Claeys-Kulik A.-L., Estermann T. (2015) *Designing strategies for efficient funding of universities in Europe* (DEFINE Project Paper), Brussels: European University Association.

Ranga M., Etzkowitz H. (2013) Triple Helix Systems: An Analytical Framework for Innovation Policy and Practice in the Knowledge Society. *Industry and Higher Education*, vol. 27, no 4, pp. 237–262.

Scott W.R. (2014) *Institutions and organizations: Ideas, interests, and identities* (4th ed.), Thousand Oaks, CA: Sage.

Sjoer E., Norgaard B., Goosens M. (2011) *Implementing Tailor-made CEE in Theory and in Practice. The Knowledge Triangle as a Conceptual Tool* (Paper presented at the SEFI annual conference, 27-30 September 2011, Lisbon).

Unger M., Wagner-Schuster D., Polt W. (2016) Austria: Place-based dimension in higher education policy making. *Enhancing the Contributions of Higher Education and Research Institutions to Innovation* (Case Studies Background Document for the OECD High Level Event on the Knowledge Triangle, 15-16 September 2016, Paris), Paris: OECD, pp. 12–14.

Veugelers R., Del Rey E. (2014) *The contribution of universities to innovation, (regional) growth and employment* (EENEE Analytical Report no 18, 01/2014), Brussels: European Commission.

Wallin J. (2006) *Business Orchestration*, London: Wiley.

Wise E., Berg M., Landgren M., Schwaag S., Benner M., Vico E.P. (2016) *Evaluating the Role of HEI's Interaction with Surrounding Society — Developmental Pilot in Sweden 2013–2016* (Vinnova Report VR 2016:09), Stockholm: Vinnova.