CESAER

ROLE OF UNIVERSITIES OF SCIENCE AND TECHNOLOGY IN INNOVATION ECOSYSTEMS: TOWARDS MISSION 3.1

WHITE PAPER

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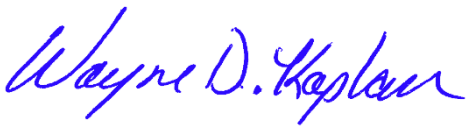
LETTER FROM THE VICE PRESIDENT

Europe's economic competitiveness in a globalised world depends on its ability to develop and translate excellent and groundbreaking scientific knowledge into the world market. Science and Technology (S&T) universities of are responsible for training highly skilled graduates in S&T, they carry out cutting edge research, collaborate with industry, and create start-ups. They operate as critical anchors of their regional innovation ecosystems, and this paper argues that they can and do go beyond that to perform a role orchestrating those systems by providing a leadership role in conjunction with regional authorities and business organisations. It is certainly their role to ensure excellence in science, and thus excellence in the technology they transfer to the community.

As Vice-President for Innovation & Impact, I call your attention to the proficiency of S&T universities to function as engines of innovation and provide society and its economic system with the needed entrepreneurial and innovation skills, while mobilising local and global knowledge. Based on a wide consultation, several meetings and concrete case studies, this white paper provides very clear examples of how universities of S&T around Europe are fulfilling this role. However, this is not yet sufficiently acknowledged by policy makers and funding authorities, resulting in inadequate funding mechanisms and far from optimum innovation ecosystems.

I thank the Co-Chairs of Task Force Innovation, Tim Bedford and Bram Wijlands, and all the authors of this white paper, as well as all the Members of CESAER that contributed with responses to the surveys on a) the role of universities in innovation ecosystems and b) innovative and entrepreneurial mindsets. A special word of gratitude to all those that developed the case studies, an exercise that not only provides the examples that illustrate the key messages of this white paper, allows for valuable best-practice sharing, but also was an opportunity for self-learning and institutional development.



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EXECUTIVE SUMMARY

Europe must make a step change in the quality and effectiveness of its innovation system. This paper argues that S&T Universities can and do play a vital coordination role in building regional innovation ecosystems to ensure that Europe can build a highly competitive knowledge-based industry for the future. There is strong evidence of the challenge that Europe has today in creating new innovation from the wealth of new knowledge created here (see e.g. Lamy report), widespread recognition that public and private investment on innovation must be increased, and consensus that new thinking is required about the way we support economic growth and societal impact through knowledge-intensive innovation ecosystems. This new thinking aims to accelerate the growth of European technology-based companies that meet the challenges of our society, and ensure that the benefits of our investments are retained to boost the prosperity of Europe.

We argue that S&T universities are at the heart of this envisioned future, playing an open and collaborative leadership role in their regional ecosystem. They are leading players in innovation - providing new talent with innovation skills and entrepreneurial attitudes, creating and accessing new applicable knowledge, and driving regional and national innovation ecosystems through collaborative partnerships with industry, research and technology organisations, and public authorities. This is not new, indeed most of Europe's key Research Infrastructures and Research and Technology Organisations (RTO) have emerged from, and developed in close collaboration with, S&T universities. The open and collaborative leadership role we envisage here goes beyond the more passive "Third Mission" and could be called "Mission 3.1".

This white paper presents five key messages on the role of S&T universities in innovation ecosystems. Chapter II on S&T universities are mission-oriented and innovation leaders, details how they perform a wide range of activities aimed at co-creating innovation with different actors of regional and local ecosystems (government, companies, incubators, accelerators, venture capitalists and banks, etc.), and support the impact of S&T advances for economic, social and environmental development and well-being. The old ´linear model of innovation´, while useful at a broad conceptual level, does not provide sufficient interaction between innovation actors (developers, users, researchers and businesses) to be successful in the context of increasingly complex challenges. Innovation is a non-linear and risky undertaking, requiring ideas, talent, funding. Continuous interaction between S&T on one side and society on the other is key for success, and it requires infrastructure (incl. physical assets, relational and knowledge sharing capital) to be shared within a regional ecosystem.

Chapter III on S&T universities as innovation system integrators, demonstrates why they are agents of change and have a high and structuring impact in their host regions and countries. They act as anchor institutions by collaborating with the actors of their ecosystem, sponsoring innovation, sharing resources, knowledge, competences and RII. This results in sustainable consolidation of innovation districts if supported adequately. S&T universities are at the forefront of developing innovation districts and wider innovation ecosystems. Recognising that there is no single route to the development of such ecosystems and that different regions and countries naturally have differing sets of organisations supporting innovation, S&T universities have taken flexible and collaborative approaches to creating the necessary support structures. Leading in partnership with public and private agencies, S&T universities have a track record of creating such infrastructure, showing their ability to provide a leading role in developing the necessary partnerships.

Chapter IV addresses S&T universities as engines of innovation. S&T universities are among the few institutions investing (money, time and other resources) directly in high-risk research through Proof of Concept programmes, collaborate with different actors in order to increase the Technology Readiness Level (TRL) of inventions. S&T universities are investing in the so-called valley of death (stage between invention and product development), with focus on impact, operating according to different dimensions of direct support and networking. They make research results available to foster innovation through specific units, Technology Transfer Offices (TTO) and in different forms (patents, startups, collaborative research, etc.).

Chapter V demonstrates S&T universities as a source of entrepreneurship and innovation skills. Collaboration with industry and entrepreneurship education are key aspects needed to support each step in S&T maturity evolution and to successfully conclude this process. S&T universities provide entrepreneurship education to students and academics, also through the provision of mentoring and tutoring programmes and business competitions.

Chapter VI explores S&T Universities as pillars of global open science. They network with other universities and companies in order to exploit opportunities coming from research and to integrate different knowledge sources and provide access to a vast range of contacts. They show similar patterns of action across Europe and promote open science and open innovation.

Recommendations are provided in Chapter 7. An underlying recommendation to all others is tis a crucial aspect of the strength of the innovation system. The latter is built upon the quality of the science produced. While much emphasis is put on the processes that bridge scientific outputs with the market and society, policies and institutional strategies must not forget the starting point: sufficient critical mass of excellent science.

We include here the general recommendations for funders and policy-makers:

- Direct funds to promote solid and adequately evaluated innovation ecosystems.
- Funds need to deliver more early stage and Proof of Concept schemes. Flexible funding, simple, continuously open (responsive mode) and bottom-up is crucial.
- Use S&T universities as strategic partners in better communicating EU instruments as intermediaries with the local network and set clear targets, mandates and incentives for the development of innovative and entrepreneurial universities;
- Policymakers should fund innovative and entrepreneurial skills, learning processes, networking and spaces for creativity, based on S&T universities infrastructure and acquired knowledge in providing mentoring for these activities.

And for decision-makers and practitioners at S&T universities:

- Benchmark more. Learn from universities which are already driving their ecosystems and further develop engagement with companies, especially with SME which lack critical resources to prove their technology.
- Develop sound and appropriate governance structures to ensure that the innovation processes can be embedded within the university strategy.
- Open RII to the relevant ecosystem stakeholders and combine this with training and proof-of-concept schemes to reduce the ´stickiness´ of new knowledge.
- Develop a consensus-view on the promotion of innovative-mindsets, involve industry partners through innovation challenges to seed creative thinking, strive to support entrepreneurial networking, and enhance the entrepreneurial ecosystem through the creation of networks comprising a range of actors.

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INTRODUCTION

Europe is effective at generating knowledge, but it is less effective in transforming it into innovation. Compared with the United States, European regions perform satisfactorily in the number of scientific publication and citations (measure of knowledge generation), but have a comparative disadvantage in turning that knowledge into innovation, as demonstrated by several indicators, amongst them a low number of patent applications per million population (measure of innovation).

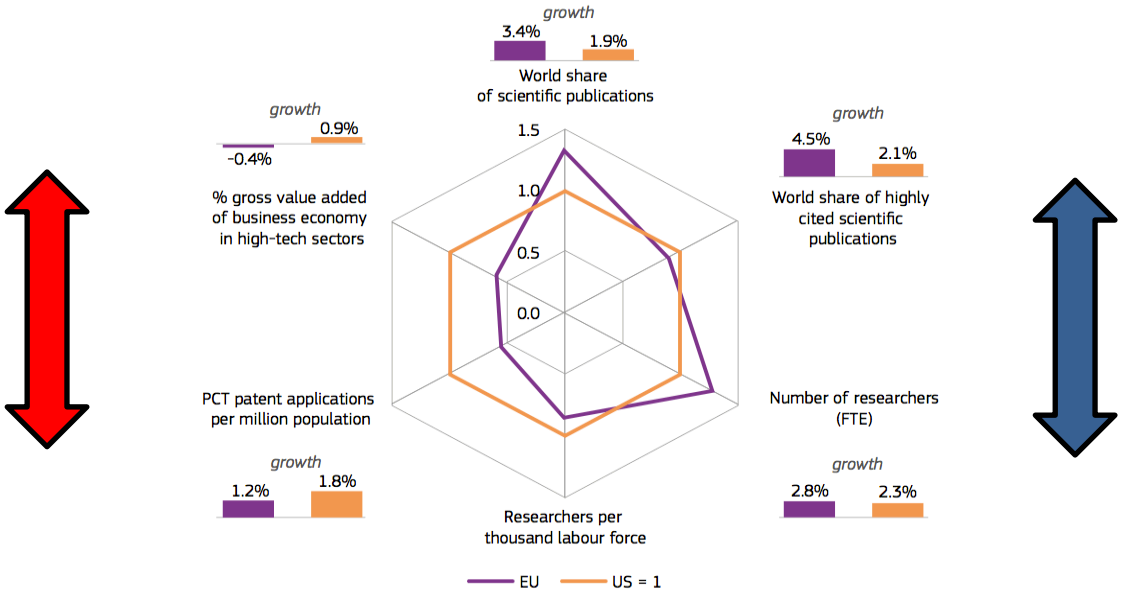

Figure 1 Comparative and growth rates of scientific publications, highly-cited scientific publications, researchers, patent applications and valued-added of high-tech sectors in the EU and the USA. Source: (Lamy et al., 2017)

From a public policy perspective, this reality has been tackled through specific measures, which often isolate the target beneficiaries from their innovation ecosystem. Even though financial support to knowledge-based innovation requires a multifaceted approach, there is ample evidence that subsidising one type of stakeholder in isolated fashion will not bring about structural change in the innovation system in the shortest possible period. Either because of lack of sufficient funds to make a significant difference regarding critical mass or because the incentive does not promote the desired outcome. Consider the example of the SME instrument programme, where the increasing quality of proposals make success rates prohibitive (European Commission, 2017); or the funding of SME to hire PhD holders, generally implemented with very low success rates at national and regional level; or also the pull-style funding to companies to buy services from universities or RTO, effectively pushing organisations towards service models that are too market dependent to foster long-term and excellent research and innovation uptake by private companies. On the other hand, where an ecosystems approach was applied, results excelled expectations and regional, national and international value-chains w/ere structured with short, medium and long-term impact. Some of the case studies presented in this paper are good examples, namely those referenced in Chapter 2 from the University of Strathclyde and *Politécnico di Milano*. It is not surprising, thus, that a more integrated approach to research and innovation funding is now an important part of the Horizon Europe approach to funding and evaluation across all its pillars.

Universities have engaged in profound transformations of organisational practices and strategic orientation, acknowledging the need to adapt and better contribute to translate knowledge to market and society. Almost all our Members have established a TTO to commercialise research results, exchange and transfer knowledge and technology to their region and have added several curricula and extra-curricular entrepreneurial courses (entrepreneurship education) to stimulate the entrepreneurial attitude and skills of students, who potentially start or be part of entrepreneurial firms with impact on regional development.

Universities are often obliged to fund the technology development process themselves and to devote financial resources to the most critical phase between invention and product development (TRL 4 to 6), when commercial concepts are created and verified, appropriate markets are identified, and protectable Intellectual Property (IP) is developed. There is little or no structured support to universities for this mission, often reliant on their own funding and *ad hoc* project support. Our Members were therefore led to consider the following questions and to highlight best practice for the role of universities in innovation ecosystems:

a) How can we ensure support for flexible routes and funding to strengthen universities' own ability to identify and stimulate open innovation and innovative mindsets so that universities can support the growth of open innovation ecosystems?
b) How can we up our game further and learn from each other, in terms of leadership, science base, open innovation, and development of innovation talent?

Our Members have supported the establishment of the European Innovation Council (EIC) and have made detailed proposals on its implementation. CESAER entered into dialogue with the Directorate-General for Research and Innovation (DG RTD) and the Joint Research Council (JRC)of the European Commission, carried out surveys to demonstrate their role and to support policy development and design funding instruments, and are strategically committed to promote innovation for societal and economic impact. The mission and activities of S&T universities are strongly aligned with the objectives of this white paper. Building on the experience of our Members, the aim of the white paper is to identify approaches to innovation and entrepreneurship in regional innovation ecosystems, stimulate entrepreneurship and deliver innovative mindsets, work across disciplinary borders, strongly collaborate with business, industry, public services and citizens, promote open science, open innovation and openness to the world. We consider that important steps were taken with the development of this white paper. The methodology of the research included desk research, data collection through a survey, case studies and consultation with our Members.

We investigated the different activities that universities perform to foster their regional innovation ecosystems through a questionnaire. The 19 respondents were mainly vice rectors and heads of TTO or equivalents. Preliminary findings were discussed in two workshops held in Budapest and Turin with the universities participating in the survey. The questionnaire was organised into four sections aimed at (i) identifying the most important innovation-enabling activities performed by universities (ii) defining the nature of the engagement with the ecosystem (including the stage of the innovation lifecycle where universities collaborate with industry), (iii) defining the main sources of funding dedicated to innovation at the ecosystem level, (iv) identifying the execution of specific activities designed to support start-up creation and growth. Questions in the questionnaire use both Likert scales and binary variables.

MISSION-ORIENTED AND INNOVATION LEADERS

This chapter focuses on the role of S&T universities in innovation ecosystems and promotes the understanding of the mechanisms through which they contribute to generating innovation within their ecosystem in terms of value and uniqueness.

Universities' research and innovation activities contribute to furthering societal challenges and goals, both locally and globally, through the unique capacity of blending multidisciplinary approaches into applied research and innovation domains. This is often supported by essential infrastructure and collaboration with a wide array of stakeholders, which concur with setting the path of the university R&I agendas. By their direct relation with not only diverse but often local stakeholders (from public to private entities), S&T universities play a lighthouse role, indicating the way forward and contributing through science and technology advances for economic, social and environmental development and well-being.

"The idea behind the UPC Innovation Ecosystem is to focus on interconnecting, coordinating, managing and leading a range of actions aimed at providing society and the productive fabric with projects, technology proposals and sources of innovation that have a positive impact on the economic development of the region."

There are different reasons explaining why universities may be considered as innovation leaders. These are related to the different mechanisms through which universities contribute to the innovation ecosystem, while adopting a mission-oriented approach: provision of appropriately skilled human capital via teaching (first mission), advancement of scientific and technical knowledge via academic research (second mission) and transfer of knowledge and technology from academia to industry and society via technology transfer (third mission).

Indeed, universities through knowledge generation and technology transfer activities, are considered the engine of social, cultural and economic development (Etzkowitz et al., 2000). Regarding the third mission, universities perform several innovation-enabling activities including patenting, licensing, spin-off, research collaboration, consulting, networking, entrepreneurship education and start-up assistance. In short, universities perform a wide range of activities to foster innovation. See, for example, the *Universitad Politécnica de Catalunya* (UPC) Innovation Ecosystem approach, or the innovation strategy of Delft Univesity of Technolgoy (TU Delft):

"TU Delft strategy to innovation pivots around the following key pillars: entrepreneurial education, identification and protection of new knowledge that can lead to successful innovations, support to techno-starters and efficient collaboration with external stakeholders."

It is interesting to note that this distinctiveness of S&T universities manifests itself in practice when analysing the range of activities that are dependent on university action or engagement of other entities with universities. Most medium-sized RTO, for example, tend to focus on very high TRL when holding no or very little cooperation with universities, whereas those that collaborate more with universities or, as in many cases, are close partners or even part of the university structure, have a higher capacity to deliver research and innovation related services starting from lower technology maturity levels. This is even more so when these organisations collaborate in advanced research and training programmes, which only doctorate-granting universities can provide.

BEST PRACTICES

Below we provide two best practices mission-oriented and innovation leading S&T universities.

UNIVERSITAT POLITÈCNICA DE CATALUNYA (UPC)

The UPC Innovation Ecosystem brings together the work of different areas, agents and processes, allowing a greater outpouring of transfer opportunities, increasing the number of innovative projects, reinforcing their growth and approach to market. It coordinates actions, programmes, interests and needs of the different agents of the ecosystem, increasing the degree of public-private collaboration through the added value that the UPC brings to the business fabric, facilitating innovation processes.

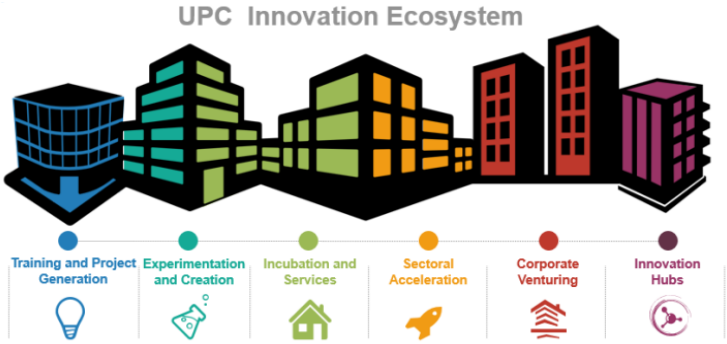

Figure 2: The UPC innovation ecosystem

It aims to generate a seal of quality and reference that identifies a global process and holistic space of:

- Training of talent in fields as innovation and entrepreneurship;
- Generation, growth and maturation of innovative projects;
- Preparation and filtering of corporate acceleration projects;
- Building spaces for the creation and generation of open public-private innovation through Innovation Hubs.

DELFT UNIVERSITY OF TECHNOLOGY (TU DELFT)

TU Delft regards facilitating and promoting the transfer and application of knowledge through innovation as its social mission. This means the translation of novel knowledge into innovative products, services, processes and new activities. In order to strengthen these activities, TU Delft focuses on the stimulation of entrepreneurial activities through a holistic approach that includes different support programmes tackling the different stages and actors relevant to innovation. The TU Delft Holding, with its sub-holding Delft Enterprises, plays an important facilitating role in this process. Intensive collaboration with the business community is crucial in supplying society with the developed products and services. TU Delft is committed to improving and expanding the cooperation with the business community at the international, European and national levels. Cooperation with regional knowledge institutions, companies and governmental bodies - by means of regional innovation clusters, for example – plays a significant role. The current TU Delft Strategic Framework 2018-2024 includes as one of its main objectives to intensify its engagement in the already wide range of multi-stakeholder Public-Private Partnerships as ideal enablers of collaboration between businesses, government and research.

INNOVATION SYSTEM INTEGRATORS

This chapter demonstrates why S&T universities are agents of change and central to well-functioning innovation ecosystems. They act as anchor institutions by collaborating with the actors of their ecosystem, sponsoring innovation, sharing resources, knowledge, competences and RII. This results in sustainable consolidation of innovation regions and value-chains. They are conscious of their socio-economic role, and are flexible in adapting to the specific conditions of local ecosystems and in creating multiple links with surrounding stakeholders:

"In partnership with the (Glasgow City) Council, Scottish Enterprise, Entrepreneurial Scotland and the Chamber of Commerce, the University of Strathclyde has established the Glasgow City Innovation District (GCID). This brings together all the parties in a commitment to develop the district of the city around the Technology and Innovation Centre (TIC) and Tontine into an innovation zone."

Today's rapid scientific and technological developments continuously create new opportunities to business (in diverse areas such as industry 4.0, advanced materials, big data, artificial intelligence, quantum technology, biotechnology, among others[1]*),* each based on a complex set of complementary competencies. The complexity and complementarity of new technologies require new forms of collaboration within a broad set of actors in a specific local ecosystem, in order to generate innovation in a specific industrial sector. In this way, there is a need for new approaches to transfer of knowledge and technology from universities to business and industry, and to develop a new generation of entrepreneurial innovation leaders (so that Europe becomes able to fully exploit its advancement of research and knowledge).

S&T universities are acting as key thus anchor institutions within their innovation ecosystems, especially when they become able to integrate the process of knowledge creation with its application in different industrial fields. This is the result of the ability that S&T universities show in collaborating with a very diverse type of actors, from local government to industrial partners, investment funds, RTO, etc. This is consistent with data we collected: Figure 3 shows a general ability to work with several actors, while data in Figure 4 indicates the breadth of the activities performed (that span from basic research to spinoffs).

[1] The CESAER Task Force S&T in the 21st Century is now developing a study on the future trends of artificial intelligence, quantum technology and biotechnology knowledge domains, in research, innovation and societal impact.

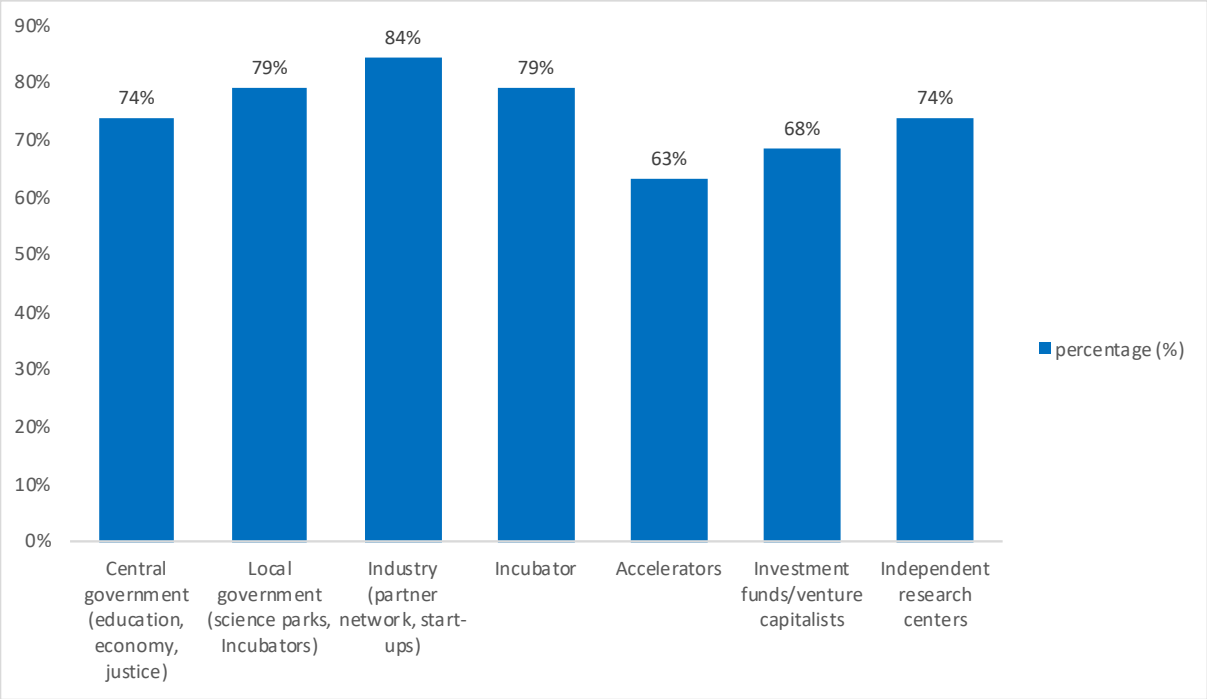

Figure 3: Percentage (%) of universities collaborating with ecosystem actors (0%= no universities collaborate with a specific actor; 100 %= all the universities collaborate with a specific actor)

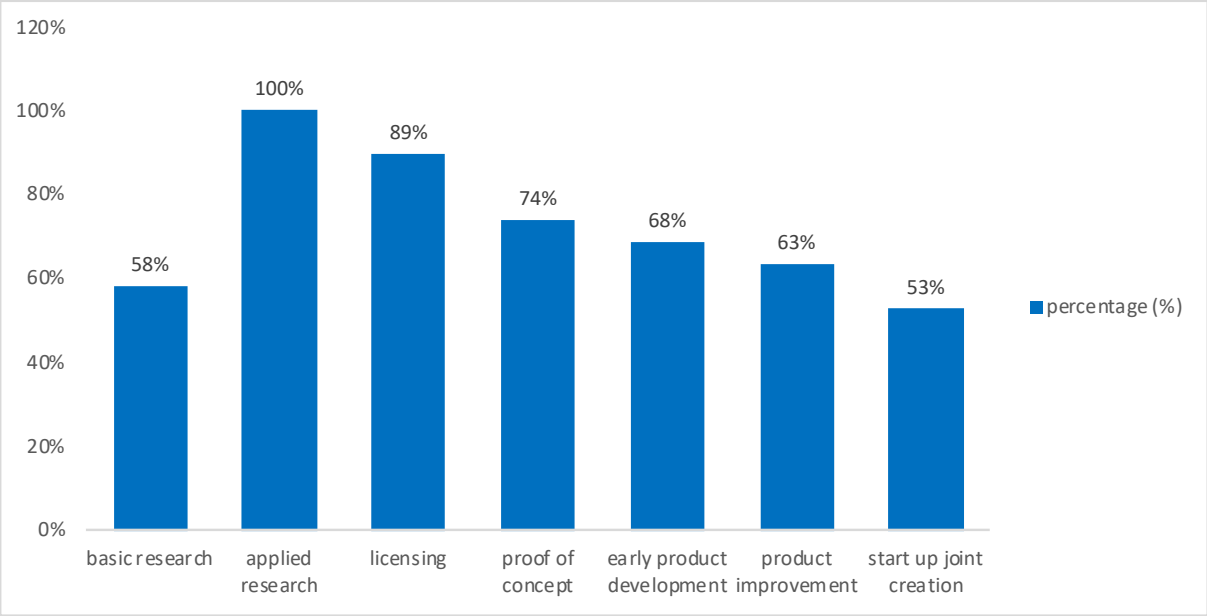

Figure 4: Percentage (%) of universities collaborating with firms in a specific phase of the innovation/technology lifecycle

Collected data and case studies show how S&T universities contribute to the innovation ecosystem by sharing their research infrastructure and developing their leadership both at exploiting existing knowledge and exploring new technical trajectories. Very often universities act as the organisation that coordinates the activities of several actors in a synergic way while at the same time providing leadership and vision. See, for example, the cases of Aalto University (Rissola et al., 2017) and Politecnico di Torino (Colombelli et al., 2017).

The RII shared by S&T universities include state-of-the-art equipment, facilities, expertise and know-how, and collaborative spaces which unleash the potential of innovation. Some universities co-own and share such infrastructure with industry and provide office space to firms, aimed at increasing the collaboration and ultimately to generate innovation. Such access from business and industry, public services and citizens to universities' RII is crucial to the innovation process to turn high-value concepts into practice and to the market. Sharing speeds up the innovation process, reduces risk, increases acceptance of new ideas, products or concepts, maximises the sharing of new knowledge and reduces the negative effects of ´bottlenecks´ in innovation processes.

"The Technology Transfer Office (TTO) of *Politécnico di Milano* (PoliMi) and PoliHub (Startup District and Incubator) work actively in spreading the innovation and entrepreneurial culture inside the University. Through the TTO and PoliHub, they build networks for the development of long-standing partnerships with other universities and RTO and work closely with others TTO and incubators association like NETVAL (the Italian TTO'S association), PNI CUBE (the Italian association of incubators and academic business plan competition) and others."

Collected data and case studies confirm that universities have a double role (Amezcua et al. 2013): Firstly, they ´buffer´ or moderate the dependence of existing organisations from environmental threats (mainly increasing international competition and new technologies) by providing resources to the ecosystem (both ´hard´ support through funding assistance - see Chapter 4, for more detail - and ´soft´ support through mentoring, training, advising and consulting). Universities are, in this way, core integrators of open innovation ecosystems. Universities support firms to develop new competencies through training and knowledge transfer. Secondly, they ´bridge´ or connect organisations acting as an innovation ecosystem integrator. In this respect, universities network with firms, research centres, banks, venture capitalists and business angels to exploit opportunities for innovation and connect them.

We see this integration role as going beyond the traditional "Third mission" of universities. In this role they are actively, and collaboratively, working with other actors to improve the quality of the innovation ecosystem. This might be called "Mission 3.1".

BEST PRACTICES

UNIVERSITY OF STRATHCLYDE (STRATHCLYDE)

In 2015 the Technology and Innovation Centre (TIC) opened at Strathclyde's city centre campus. Together with the Innovo building, which provides flexible, reconfigurable space for companies, the TIC is a hub for multidisciplinary research and innovation, as well as being a major conference and meeting venue for academia, industry and other government agencies.

A particularly disruptive programme linking enabling tech with manufacturing has been the Continuous Manufacturing and Crystallisation Future Manufacturing Research Hub which includes as industry partners AstraZeneca, GSK, Novartis, Bayer, Lilly, Takeda, Roche and Pfizer. The programme supports the transition from batch to continuous medicine manufacturing, dramatically reducing energy and other production costs, and enabling cost-effective small-scale manufacturing for niche medicines.

The university supported Glasgow City Council recently in establishing Tontine, an accelerator for innovative young companies close to the TIC, and now in partnership with the Council,

Scottish Enterprise, Entrepreneurial Scotland and the Chamber of Commerce, the University has established the Glasgow City Innovation District (GCID).

This brings together all the parties in a commitment to develop the district of the city around TIC and Tontine into an innovation zone. The central part of this will be the new TIC Zone, in which the university is further developing its focus on clusters in QuantumTech, HealthTech, Industrial Informatics, FinTech, SpaceTech and 5G/Next Generation Comms. Each of these clusters includes collaboration with national and local partners, and with translational organisations, and they are already attracting inward investment.

The University's ability to grow large scale, highly competitive and attractive research centres is amply demonstrated by its establishment of the Advanced Forming Research Centre (AFRC) in 2009 with the support of the governmental agency, Scottish Enterprise. AFRC started with ten employees and founding industrial members Rolls Royce, Boeing and Timet. It is now a hub of the UK High Value Manufacturing Catapult, has more than 130 staff, and has added Aubert & Duval and Bifrangi to the Tier One members and more than 20 companies as Tier 2 members. It provides R&D and a host of advisory services to companies in and out of the region, including a new lightweighting centre collaborating with local aerospace companies.

POLITÉCNICO DI MILANO (POLIMI)

With approximately 42,000 students, PoliMi is the largest university for Engineering, Architecture and Industrial Design in Italy and it is ranked as one of the most outstanding European universities in these fields. The university has seven campuses located in Milan and other nearby Italian cities, and it is organised into 12 departments, devoted to research, and in 4 schools, devoted to education.

The foundations of the University innovation ecosystem are:

- High quality research (attested by the various international rankings);
- A close relationship with the industrial world, highlighted by the volume of collaborations with companies supported also by the capacity to make technological facilities available to businesses;
- A strong inclination to technology transfer and entrepreneurship: POLIMI was among the first universities in Italy to understand the importance of enhancing the innovation arising from its teaching and research activities.

The PoliMi innovation ecosystem mainly relies on two operative structures: the TTO, that supports the development and transfer of IP stemmed from research results and activities (such as know-how, patents, Designs, trademarks, software) and PoliHub - Startup District and Incubator, a company providing support to high innovative startups operating in different fields of innovation.

The TTO and PoliHub work actively in spreading the innovation and entrepreneurial culture inside the University. They build networks for the development of long-standing partnerships with other Universities and Research Institutions and work closely with other TTO and incubator associations like NETVAL (the Italian TTO association), PNI CUBE (the Italian association of incubators and academic business plan competition) and others.

ENGINES OF INNOVATION

S&T universities are investing on a unique array of activities aimed at bridging the gap between research results and innovation, ranging from the role of education in entrepreneurship to support services in the form of research commercialisation, collaborative projects or even support in funding. This means that S&T universities provide resources to students, start-ups and established firms to create innovative products and/or services (universities sponsor the ecosystem, thereby promoting its integration).

In particular, results of our questionnaire found that S&T universities perform six relevant innovation-enabling activities: research commercialisation, academic engagement, support to start-up creation and growth, funding support, entrepreneurship education to students and creation of entrepreneurial climate within the university. Among these, research commercialisation, entrepreneurship education and academic engagement have the highest scoring in terms of importance (Figure 5). In the following chapter we will discuss these activities in detail while providing the results of the survey.

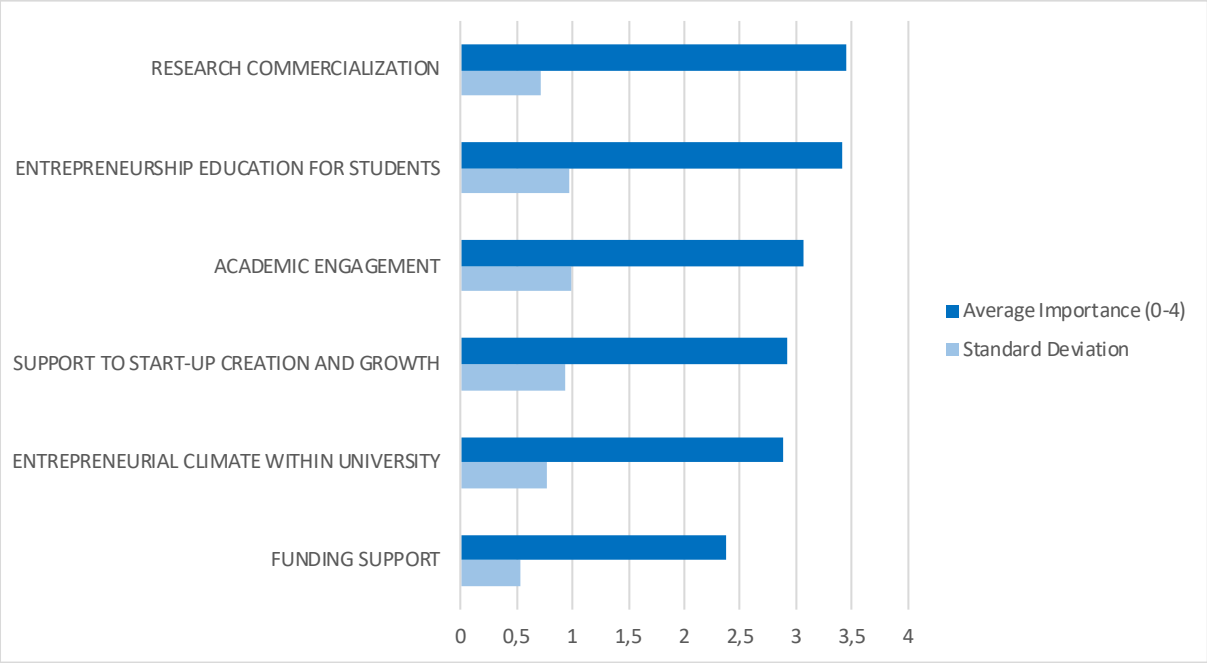

Figure 5: Average importance given to innovation-enabling activities (0= not important; 4= very important)

Research commercialisation includes all the activities aimed at valorising research results and transferring them to industry and society (as patents, licensing agreements, the creation of start-ups, etc.). These activities require administrative effort and specific competencies and therefore need dedicated organisational units (i.e. TTO) that perform administrative functions, negotiation and management of research contracts and partnerships as well as diffusion of an entrepreneurial culture within the university. As Figure 6 shows, on average the universities attribute a high importance to all the activities associated with research commercialisation.

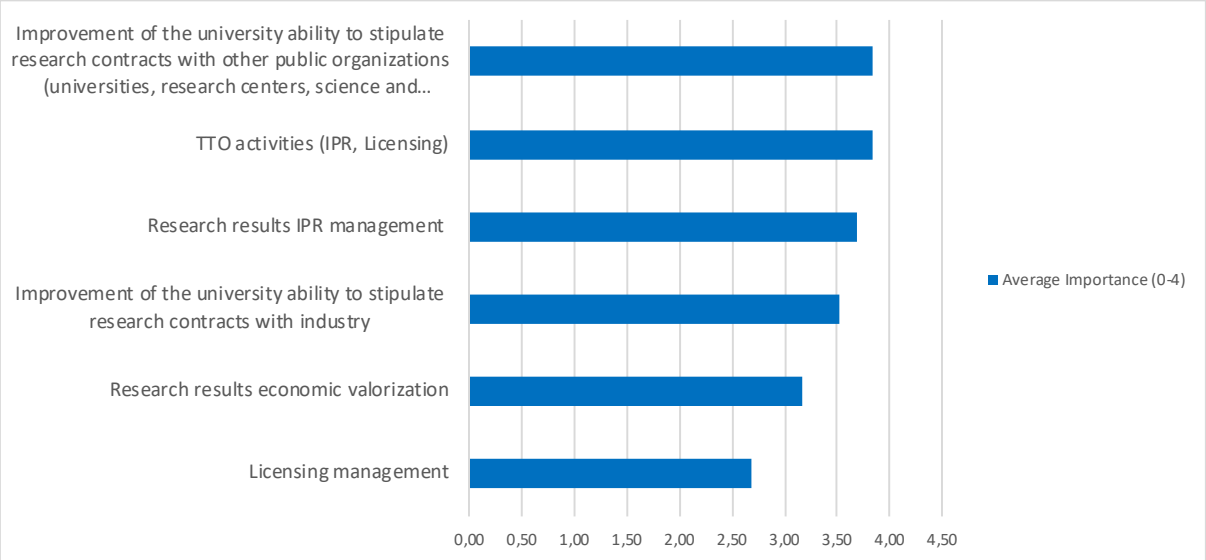

Figure 6: Average importance given to research commercialisation activities (0= not important; 4= very important)

Academic engagement refers to the level of engagement in knowledge-related collaboration of the university with ecosystems and includes networking, training, collaborative research, contract research and other forms of knowledge exchange (Perkmann et al., 2013). Transfer of knowledge from labs research to innovation activities and economics / social activities takes place in multiples forms and different stages with different stickiness of knowledge and funding requirements. Flexible support/sponsorship and collaboration with their relevant ecosystem are key aspects (sharing of research infrastructure and specific technical and scientific knowledge, start-up creation, etc.).

Contrary to what most linear perspectives of research and innovation systems suggest, S&T Universities do provide services directly to industry, mainly applied research, licensing and proof of concept. For example, the Research Promotion Unit of the Technion - Israel Institute of Technology (Technion), is successful in identifying the most suitable researchers and facilities based on the industry's technological needs, promoting customised collaboration, closely following the entire process and assisting in the various stages.

Innovation is inherently collaborative and the innovation process should consider the research and innovation cycle as a whole if truly sustainable, long-lasting and successful results are to be achieved. Bringing people and organisations together, in diverse ways, is a role of growing importance in most universities and, thus, in innovation ecosystems. In addition to the role of system integrator needed to bring together different actors (as discussed in Chapter 3), universities support their ecosystem with other mechanisms namely international networking with other universities and companies and, to a good extent, they provide training to graduate students, scientists and industry members.

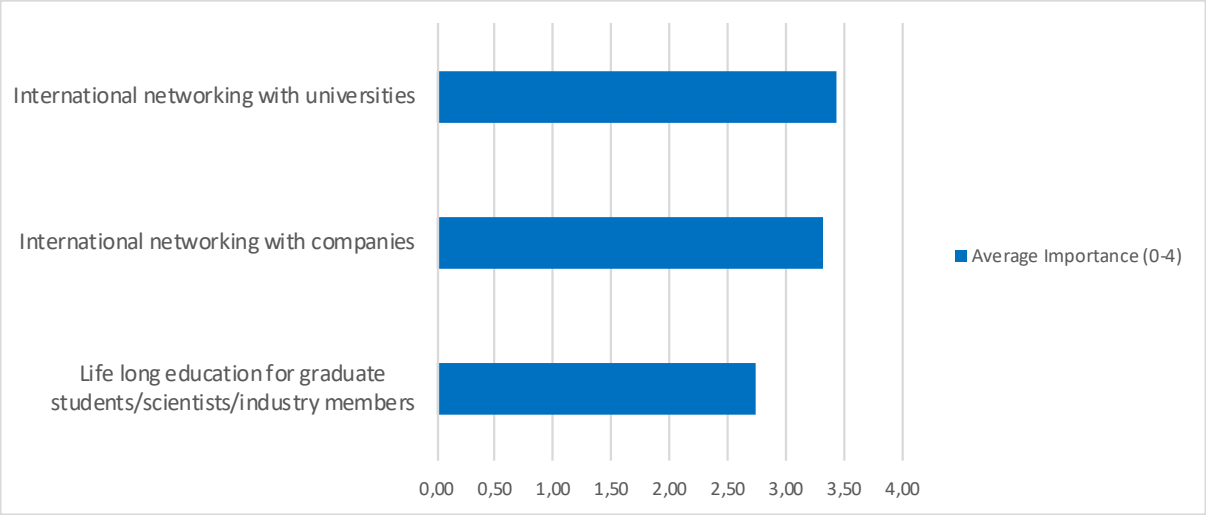

Figure 7: Average importance given to academic engagement activities (0=not important; 4= very important)

Support to start-up creation and growth refers to the activities associated with support to both students and faculty members in creating a start-up, including the first stages of development. Such activities include *entrepreneurship courses*, *mentoring programmes*, *space provision* to connect students, *business plan* development, etc. These activities have two objectives. Firstly, to protect already created enterprises from the liability of newness (Singh et al., 1986), the difficulties associated with establishing necessary resources and social relationships with the external environment (Amezcua et al., 2013). Secondly, to foster the growth of an entrepreneurial team to form a start-up. Amezcua et al. (2013) refer to these activities with *organisational sponsorship* defining it as any attempt to mediate the "relationship between new organisations and their environments by creating a resource-munificent context intended to increase survival rates among organisations" (Amezcua et al.,2013; pp 1628). Figures 8 and 9 confirm that universities have allocated significant resources to supporting start-up creation and growth. In particular, universities consider it very important to perform mentoring programmes and incubation programmes.

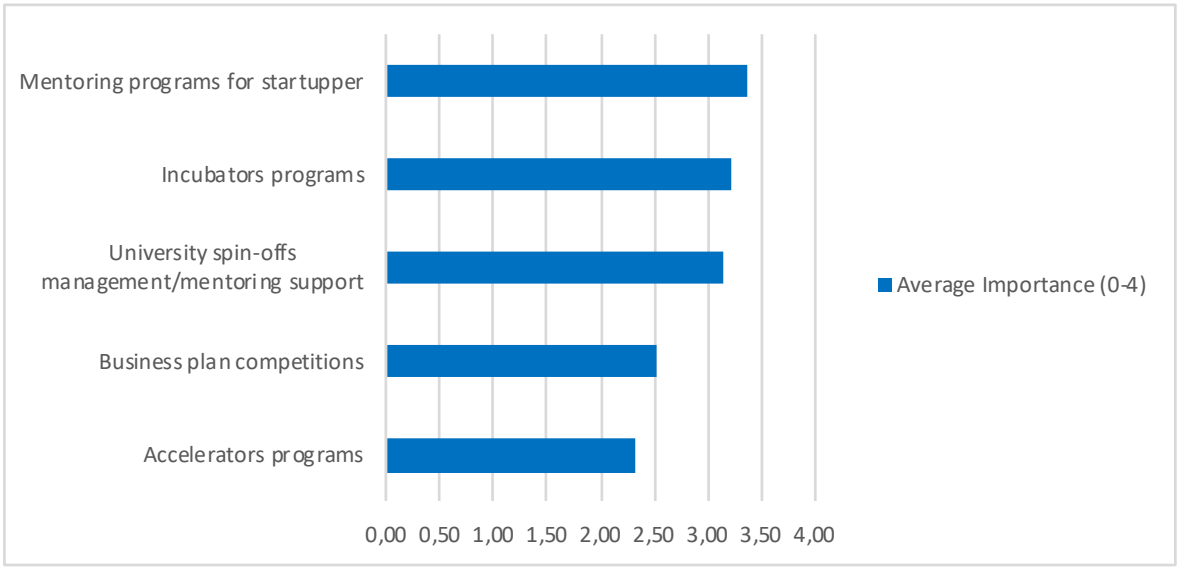

Figure 8: Average importance given to support to start-up creation and growth activities (0=not important; 4= very important)

Regarding the share of universities providing a specific activity related to supporting start-up creation and growth, the survey reveals that 89% of universities offer at least one entrepreneurship course and 84% of universities provide space and mentoring programmes to students and start-uppers. 74% of universities offer idea competitions with a prize, and 68% provide labs and research infrastructure to students.

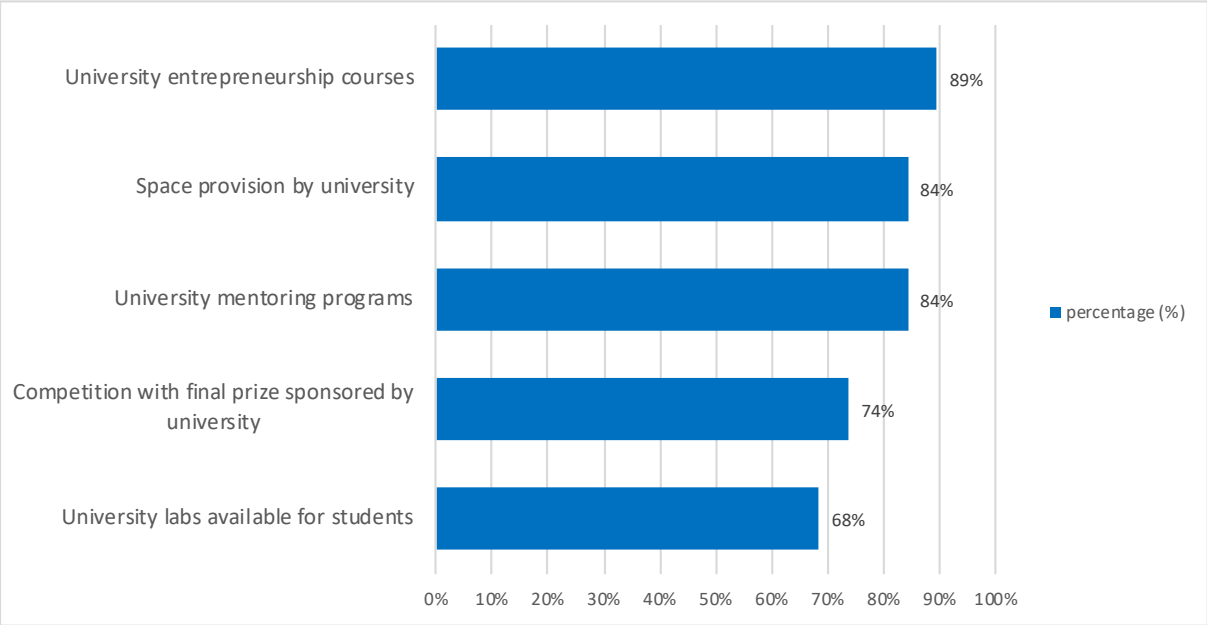

Figure 9: Percentage (%) of universities offering activities related to support to start-up creation and growth (0% no universities provide a specific activity; 100 % all the universities provide a specific activity)

A relatively new innovation-enabling activity, linked with the ones discussed above, is funding support for innovation development, often based on internal funds (this a clear signal of the lack of specific funding). With such type of support, S&T universities fund the most critical phase between invention and product development when it is fundamental to demonstrate the viability of commercial concepts. This phase has a funding gap caused by the high level of risk regarding project outcomes which exclude most private investors (i.e. firms, banks, venture capitalists, etc.) to provide funds.

In this survey we found S&T universities are among the few institutions investing their own resources (money, time and other resources) directly in high-risk, promising research in different stages (including ´Proof of Concept´ programmes), in order to increase the TRL of inventions. S&T universities are investing in the so-called innovation ´death valley´ (the stage between invention and product development), having a focus on “impact”, operating according to different dimensions of direct support and networking. They make research results available in order to foster innovation through TTO and in different forms (patents, startups, collaborative research, etc.).

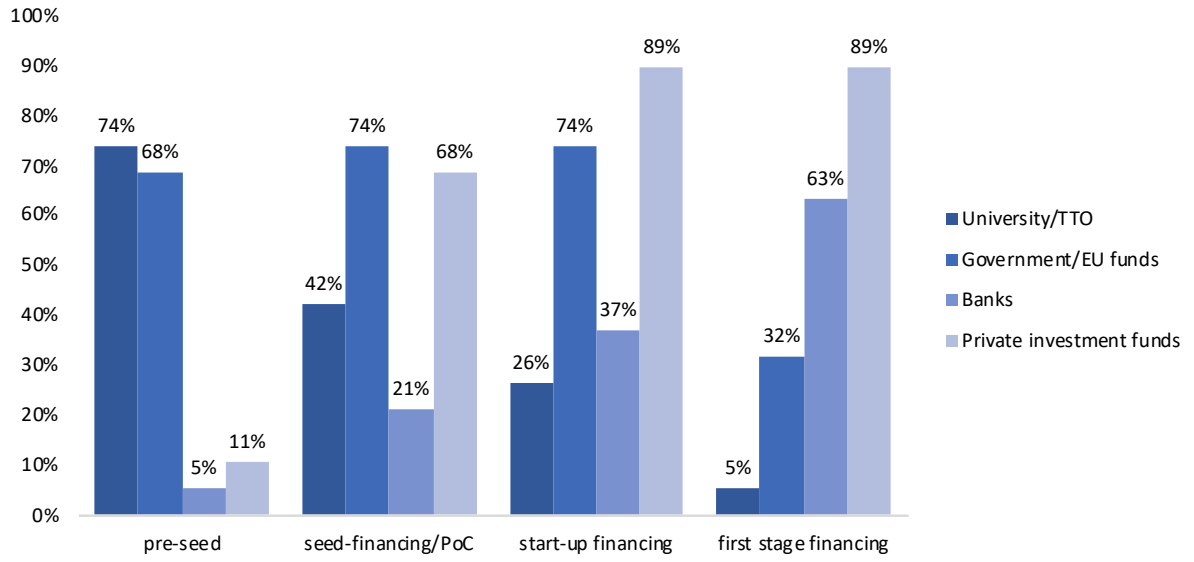

Figure 10: Percentage (%) of universitiy start-ups which get investment from the following four types of funding support according to the technology development stage: pre-seed, seed/Proof of Concept, start-up and first stage funding

Figure 10 confirms that universities are almost the only actors investing at the initial phases of the technology/innovation development: ´Pre-seed´ funding is made available by universities, in a stage where risk is too high for investors (due to the high technological risks). Seed/PoC funding is only available in some universities (42.11 %), and public funding is provided to 74% of the S&T universities, in most cases only through *ad hoc* competitive calls, requiring the use of funds initially designated to other activities. These funds only rarely address and support knowledge-based entrepreneurship in proof of concept stages. Start-up financing (funds to companies for product development and initial go to market stages) and first stage financing (funds for manufacturing and sales) are made available by private investment funds, banks and similar financial institutions, e.g. European Investment Fund (EIF). There is an opportunity for universities to play a larger role in first stage financing, especially as they have already worked at earlier stages to de-risk the technologies.

Entrepreneurship education has become an important activity for university managers, professors and researchers (Kuratko, 2005) because of the positive benefits associated of having students with an entrepreneurial attitude, skills and intention which could foster entrepreneurship and innovation, and therefore, stimulate economic growth in a region (Rauch and Hulsink, 2015). Chapter 5 will discuss in detail this important activity.

An internally oriented activity is the creation of an entrepreneurial climate within the university, including all the activities that create such a climate, training staff and faculty in the commercialisation of new technologies.

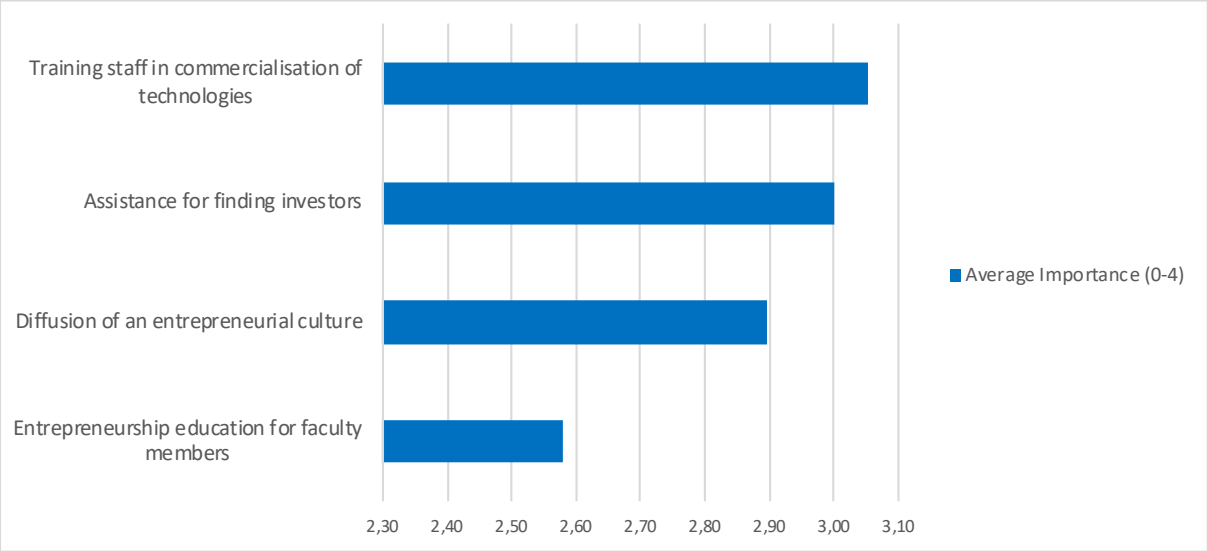

Figure 11: Average importance given to activities related to the creation of an entrepreneurial climate within universities (0= not important; 4= very important)

BEST PRACTICES

POLITÉCNICO DI TORINO (POLITO)

Politécnico di Torino (PoliTo) acts as an integrator in its knowledge ecosystem at different levels, creating and promoting exchanges of knowledge among the various actors in its regional ecosystem in an overall effort to bridge the ´death valley´ between research and innovation. The ecosystem as such favours the transfer of knowledge among the different actors by formal and informal mechanisms of ´cross-realm transposition´, which is defined as a transfer of ideas, models, and research results among the different relevant players. In this context, PoliTo not only develops new knowledge (also in the form of patents), but it also acts as a knowledge intermediary between local SME and large companies and supports the creation of spin-offs and start-ups through its incubator.

INNOVATION KEY PERFORMANCE INDICATORS	
Invention disclosures since 2010	303
Patents published application since 2010	241
Granted patents since 2010	203
Commercialised patents since 2010	80
Patents Co-Ownership rate since 2010	59 %
Spin-offs since 2004	54
Total Start-ups launched by the incubator	224

Table 1: PoliTo innovation key performance indicators

PoliTo is currently supporting the evolution of Piedmont from a ´traditional´ industrial setting (including FCA and its large suppliers, Telecom Italia, Leonardo, Thales, Comau and Magneti Marelli) to a more sophisticated and technologically diversified system, which is today only partially linked to the local automotive production system and that has progressively been reshaped to include emerging businesses in new sectors. Following this strategy, there was recently a growing focus on methods able to increase the TRL of research results developed internally, in order to facilitate the transfer to industries.

Therefore, to fill the gap between TRL 3-4 and 6-7, Polito decided to act as a proactive investor, addressing the most critical phase in the innovation process between invention (when Intellectual Property is created) and technology development (when commercial concepts are created and verified, and proper markets are identified). The PoC programme has two annual calls with a total annual funding of around 1M€ (with grants up to 50 k€) made available by PoliTo with internal funds. An analysis of completed PoCs reveals that the programme was able to increase TRL by an average of two levels (from around 3 to 5), to overcome many inhibitors to technology transfer and to create a positive incentive to innovation. It also created new opportunities for patents licensing and start-ups creation and allowed PoliTo to improve its ability to act as an integrator between university research and industrial applications. The PoC programme attracted new attention and investments from business angels (they co-invested in some PoCs), Venture Capitalists focused on technology transfer and early stages, as well as local medium-sized companies looking for new technological opportunities. Activities aimed at closing the gap between research and application are evolving, always with a strong collaboration with the regional government.

UNIVERSITY OF PORTO (UPORTO)

The innovation and entrepreneurship ecosystem of the University of Porto (UPorto) encompasses all stages of social and economic valorisation of knowledge, from its transfer to incubation, including the support to the creation of new ventures whose competitiveness relies on products, processes or business models based on scientific knowledge. In order to transform the knowledge generated in its R&D structures into effective solutions useful to companies and other organisations, UPorto has three major approaches (Figure 12): protection and commercialisation of intellectual property, development of joint projects with industry, and creation of spin-offs emerged within the university's ecosystem.

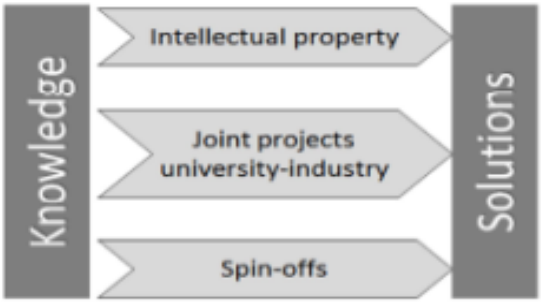

Figure 12: The University of Porto process of knowledge valorisation

This strategy is put into practice through an effective management of the innovation value chain. On the basis of the first and seond missions of the university (education and research), the creation of value is based on three major activities: knowledge transfer, the creation of new ventures, incubation.

Knowledge transfer relies primarily on UPorto Innovation, whose mission is to support the value chain of innovation promoting the best use of knowledge based on the interface between the university and industry. This TTO ensures the interconnection between the university's research centres and big and small companies. To do so, it provides technical support in three major areas: protection of intellectual property, creation of spin-offs, and link to companies.

The results achieved are significant: UPorto is the leader of Portuguese higher education institutions in terms of patents, most of them in co-ownership with other universities and companies. By the end of 2017, the university had registered more than 460 patents.

Creation of new ventures: UPorto carries out several initiatives to promote the emergence of start-ups whose competitiveness is global and based on the integration of knowledge (whether technology-based or not) in their products, processes or business models. The most relevant initiatives in this field are the successful Business Ignition Programme (BIP) and the School of Start-Ups, two complementary programmes since the former is technology-driven while the latter is mainly market-driven in nature.

Incubation at UPorto is mainly based on UPTEC. This Science and Technology Park acts not only as an incubator of start-ups as it also hosts innovation centres of large companies such as Microsoft, Vodafone, Alcatel-Lucent, Vestas and the German institute Fraunhofer. UPTEC is the largest university-based science and technology park in Portugal with a significant impact on the innovation ecosystem. More than 500 start-ups were created over the past 10 years. By the end of 2017, there were 194 ongoing projects at the park, involving more than 2,400 people in a range of areas such as nanotechnology, energy, health, biotechnology, information technologies, digital media, architecture, relationship marketing and content production. The annual impact on GDP is quite significant, reaching almost 190 million euros, and the generation of taxes is about 40 million euros per year.

To sum up, UPorto is a case of strong commitment to the creation of value based on the knowledge produced by R&D activities. To do so, the university acts as leader and integrator of resources and competences owned and controlled by both internal players and external actors. The results achieved are significant in terms of contribution for the creation of a dynamic ecosystem with high impact on the development of the region where it is located.

SOURCE OF ENTREPRENEURSHIP AND INNOVATION SKILLS

Following up on the recommendation ´Educate for future and invest in people who will make the change´ given in the LAB - FAB - APP report chaired by Pascal Lamy, this chapter explores how S&T universities have the potential to create highly innovative and entrepreneurial individuals through curricular and through extra-curricular activities. Since higher education has been of central importance as one lever to foster innovators and entrepreneurs, the European Commission has established several initiatives under the umbrella of, for example, the European Institute of Innovation and Technology (EIT) or the Entrepreneurship Action Plan 2020. Our study demonstrates that fostering innovative and entrepreneurial thinking through extra-curricular activities is of high impact. A survey was conducted among seventeen Member universities to shed light on the following questions:

1. Which attributes need to be strengthened when striving to stimulate innovativeness and entrepreneurship?
2. What extra-curricular activities are being offered by universities?
3. How are teachers and external stakeholders involved?

Regarding the first question, our Members agree that fostering creativity is of central importance when trying to promote innovators in their development. Consequently, universities are advised to provide space in creativity labs where students can live their creativity freely and meet with industry to prosper. Such space needs to become eligible for funding. On the other hand, pro-activeness, risk propensity, and networking capability are central for encouraging entrepreneurs. As such, the role of universities as the regional meeting point for entrepreneurial actors in their local ecosystem becomes even more important. Creating such meeting points in the form of university-owned incubator and/or accelerator space where individuals interested in starting a business, young start-ups, and established firms meet, is considered key. Entrepreneurial networking comprises the potential to spur a more failure-friendly culture and thus encourages entrepreneurs. To support this initiative, funding schemes should be expanded to entrepreneurial networking and learning. Entrepreneurial education needs to be opened to interested individuals from all disciplines to equip all founders from any background with the necessary skills to start and grow a business and consequently to higher the probability of starting a success story that gives back to European society. We perceive extra-curricular activities to be especially suitable for achieving this target.

Extra-curricular activities such as networking events, intense seminars, summer schools, and industry visits are already a common instrument among S&T universities to foster innovativeness and an entrepreneurial spirit. Nevertheless, universities need to engage more in supporting entrepreneurial networking to raise awareness regarding pro-activeness, risk propensity and social entrepreneurship. Moreover, universities are encouraged to open the extra-curricular offering up to all disciplines and all levels. Today, students are the focus of the extra-curricular activities as depicted in Figure 13. However, academic staff also need to be targeted more intensely and thus a two-stage approach is suggested (compare Figure 14). In the first stage, sensitisation regarding innovative and entrepreneurial traits addresses undergraduate students. In the second stage, postgraduates and academic staff are equipped with the necessary skills to innovate or establish businesses confidently. Policy-makers are advised to include those mindset funnel initiatives in future funding schemes.

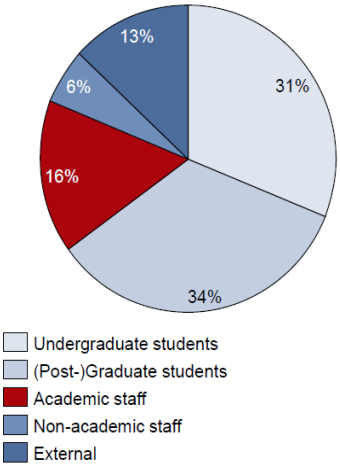

Figure 13: Target group of extracurricular activities (2017)

Stage	Sensitisation	Outcome-driven education
Primary target group	Undergraduate students (all disciplines)	Postgraduate students, PhD students, academic staff (all disciplines)
Purpose and scope of activities	Raise awareness for innovation and start-ups through visits to industry and start-ups	Equip highly educated individuals with necessary tools and knowledge to innovate, and to start and to grow a business successfully
Availability	Make available to broad audience with broad spectrum of focus topics	Offer very focused programme to a limited target audience

Figure 14: Two-stage approach for higher education innovator and entrepreneur education

The survey results show that many stakeholders - such as chairs, faculties, centres for entrepreneurship and also student initiatives - are driving many of the extracurricular initiatives (cp. Figure 15. We urge the S&T universities to invite industry partners - both established firms and start-ups - to participate more actively and to develop offerings that involve co-hosting of extracurricular initiatives on a regular basis as we believe that industry actors are capable of providing added value to interested students and academic staff that cannot be generated by internal university actors alone.

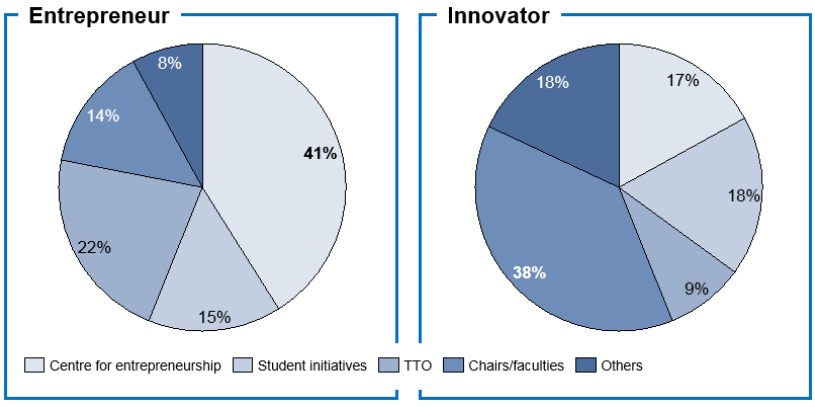

Figure 15: Responsible stakeholders for extra-curricular offering

The collected data indicates that external actors are already sharing their industry experience through guest lectures, co-hosting of events and also as trainers. Universities are encouraged to exploit this cooperation to a maximised extent. Professors and teachers take on a key role in spreading a culture of innovation and entrepreneurship. Today, the mode of involvement is rather passive for both groups of facilitators, i.e. industry partners and teachers. S&T universities are advised to support more bi-directional cooperation within the above-mentioned creativity labs or entrepreneurial networking initiatives and meeting points.

TOPIC	FINDING	RECOMMENDATION
Definition of mindset	- No one size fits all approach - No consensus among universities - Innovative minds: creativity - Entrepreneurial minds: pro-activeness, risk propensity, networking	- University: support entrepreneurial networking and provide physical space for creativity - Policy: extend funding schemes to entrepreneurial networking and provide base funding for creativity labs
Extra-curricular offering	- Wide range of offerings - Target group of post and undergraduate	- Make offerings open for innovators and entrepreneurs and enrich with soft skills - Engage student initiatives more actively - Bring doctoral students more into focus and tailor offerings to development stage
Centre for entrepreneurship	- 80% have a CoE - Main task is to coach founding teams - Organising networking events, advising on financing options	- Policy: provide base funding for CoE which are not necessarily tied to performance goals – spreading a mindset takes time and is difficult to implement and measure
Incentives for students	- Almost 50% do not incentivise participation in extra-curricular offering at all - A third incentivises through an annex to the graduation diploma	- Either stimulate participation, e.g. though prizes; or integrate into curriculum
Involvement of stakeholders	- Teaching staff and externals are already heavily involved in innovative and entrepreneurial student activity - Involvement is mostly passive and reactive	- Through integration into curriculum, proactive involvement as teaching staff could be stimulated - Collaboration with external stakeholders should become more bi-directional

Table 2: Universities have the potential to develop the future EIC stars

BEST PRACTICES

RWTH Aachen University (RWTH Aachen), KU Leuven, Norwegian University of Science and Technology (NTNU) and Tomsk Polytechnic University (TPU) below offer their best practices.

RWTH AACHEN UNIVERSITY (RWTH AACHEN)

As RWTH Aachen aims to be one of the leading entrepreneurship-oriented universities of S&T in the world, the field of entrepreneur and innovator education has been chosen as a specific facet to elaborate upon, facilitated by a strategic focus on digitisation.

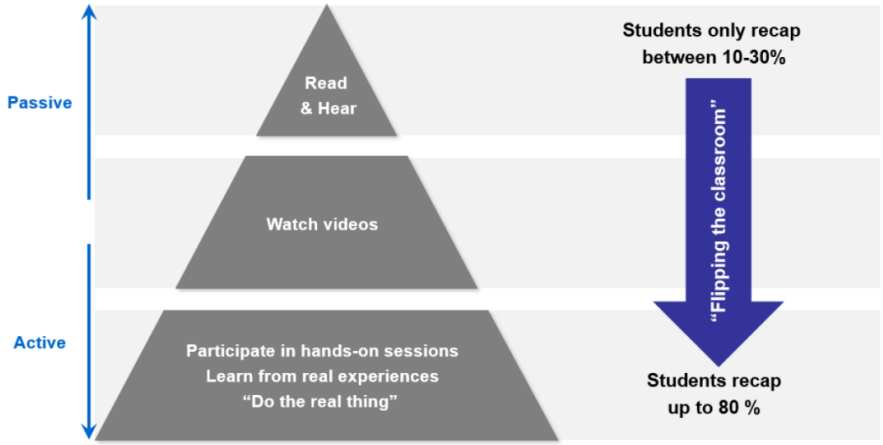

Figure 16: Baseline model of digitised teaching

Every year, more than 50 businesses are founded at RWTH Aachen. These businesses have their origin mainly in natural science and engineering disciplines. Therefore, the founders have not usually received prior entrepreneurship education as part of their studies and equipping them with the necessary skills is of utmost importance. As the university's TIME Research Area has already digitised most of its teaching content to improve the learning experience of enrolled students, it was decided to make the content publicly available in an open access format. RWTH Aachen currently offers six Massive Open Online Courses (MOOCs) on the platform edX, which was founded by Harvard University and MIT in 2012. These MOOCs cover topics such as venture capital, customer-centric innovation, and strategic management, amongst others. RWTH Aachen makes this content publicly available to anybody who is interested in learning the necessary business skills to innovate continuously and to lead a company successfully. Since 2016, more than 48,000 users from all over the world have enrolled for participation in the MOOCs. These users have to invest 6-8 hours per week over a duration of six weeks to complete one module. The learnings from the MOOCs are supported through homework assignments and participants from nearby regions around the world are teamed up by the course coordinators to stimulate exchange among them. Moreover, participants discuss learning and homework assignments in integrated forums and may participate in an online exam at the end of the course. Therefore, interested individuals get the opportunity to acquire topic-specific knowledge in a reasonable amount of time, free of charge.

In sum, RWTH Aachen follows the vision of providing high-quality education free of charge to people all around the globe. The content for the open access MOOCs is mostly generated simultaneously with internal open online courses. This keeps the investment of human resources to a minimum, while the learnings that are obtained through the open access programme also help to further improve the courses offered to enrolled students. Other Members that offer MOOCs on edX include TU Delft, ETH Zurich and KU Leuven.

KU LEUVEN

In 2014, KU Leuven launched ´Lcie´, the Leuven Community for Innovation driven Entrepreneurship. The goal of this initiative is to stimulate and support entrepreneurship with its population of students, staff and faculty. A particular characteristic of this initiative is that it is mainly managed via a bottom-up approach driven by individual community members and with significant student involvement. In the university ecosystem, Lcie is being branded as a 'one stop shop' and catalyst for entrepreneurial behaviour.

Over the last years, various KU Leuven faculties have introduced courses on entrepreneurship both at the Master and Bachelor level. To further build on and consolidate these initiatives, the University has created the Lcie Entrepreneurship Academy, which now manages a portfolio of entrepreneurship courses that can lead to a certificate of entrepreneurship (requiring a minimum of a least 18 ECTS worth of courses). The Lcie Academy is governed by an interdisciplinary steering committee.

In addition, the Lcie community has also started new initiatives that have become fully embraced by the university community. As an intra-curricular example, students have created a new course Product innovation Project. In this project-based learning format, a multi-disciplinary team of students has to develop a solution to a given problem delivered by a project sponsor, delivering a prototype and business case. This format has been inspired by similar formats developed at Aalto and Graz. Starting with one team of about ten students from three faculties, the format was rapidly adopted throughout the academic community, leading to its acceptance in 14 faculties after just three years.

As an extra-curricular example, a modular inspirational concept known as the "Learning Garages" has been implemented in the university whereby students are challenged to come up with a business case in the field of an emerging technology (e.g. Artificial Intelligence). This concept has been initiated by the Cronos Group - an IT integrator & innovator with focus on entrepreneurship - and one of the strategic partners of the Lcie network. It is noteworthy that a significant number of participants in this concept (at least one third) is affiliated with the group of Social Sciences and Humanities, indicating the potential to reach out to faculties that are often not easily associated with entrepreneurship and innovation. It also illustrates the power of strategic partnerships with external partners.

Several initiatives by the student community also provide valuable support for entrepreneurial projects. One example is IusStart, a legal clinic that has been started in 2014 by PhD students from the faculty of Law, whereby students provide legal advice for startups. At this point, the concept has been fully adopted by the faculty of Law in the form of a Master thesis for law students. Currently, very academic year, up to twenty IusStart law students provide legal advice to five to ten startups supervised by five PhD students and a similar number of law offices.

Along similar lines, the ´TechStart´ concept was initiated recently by PhD students from the engineering faculty, whereby engineering students provide technology advice to startups, thereby receiving ECTS credits.

Last but not least, since the start of the Lcie initiative, some 135 student teams have been helped by Lcie on their entrepreneurial project, resulting in new enterprises that together created more than 100 new jobs and raised over 14 million euro of external capital.

NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY (NTNU)

NTNU has a strong science and technology-orientation. NTNUs 2020-strategy clearly articulated that all students would get an introduction to entrepreneurship and innovation during their studies. In 2013, a request from a major utility company, TrønderEnergi, called for closer cooperation with the university. This extended cooperation is primarily expressed through developing a method to engage more students in the region to work with innovation and entrepreneurship. This was to be a joint effort to include all NTNU students in the innovation ecosystem and bring to life more ideas at the regional and national levels. TrønderEnergi has a long history in supporting business development in the region, and view their support of student-driven start-ups as beneficial in several ways:

- Facilitate new business growth in the region;
- Faciltitate more experience-based learning about entrepreneurial and innovation processes among students at the university;
- Inspire their own organisation to gain a mindset prepared for the revolutionary changes in their industry;
- Market themselves as an attractive employer for highly competent talents.

In 2014, NTNU launched Spark NTNU, an extracurricular entrepreneurship initiative that offers free coaching in the entrepreneurial process to all students.

The core of Spark NTNU is coaching. Students with some entrepreneurial experience, for example from running their own start-up, are coaching novice student entrepreneurs. At the time of writing, 17 students work as coaches in Spark NTNU. The fact that students perform all the daily operations of the initiative ensures a lower demand on faculty resources and the organisation may easily be increased if need be.

All university students with an idea they want to set to life are eligible for free coaching from Spark NTNU. There is an emphasis on ideas with a business goal and/or potential, but any idea or project is eligible to receive coaching. As of August 2018, Spark NTNU is coaching 64 active projects. Since its launch in 2014, Spark NTNU has been coaching over 360 projects. Taking into account the average team size of three students, this means that the initiative has supported around 1100 students so far. Among the projects that have been supported, 36 are registered as “alumni”, meaning that the projects have been turned into growing businesses and/or limited companies at a level beyond the mandate of Spark NTNU.

NICHE	# PROJECTS
Consumer hardware	2
Education technology	5
Food & Fashion	3
Games & Toys	4
Health Technology	4
Industrial Solutions	9
Marketing (Services, Platforms)	3
Non-Profits	2
Social Media and Multi-Sided Platforms	4

Figure 17: Alumni projects from SPARK NTNU categorised by niche

TOMSK POLYTECHNIC UNIVERSITY (TPU)

TPU plays a leading role in popularising innovation and entrepreneurship at regional and national levels by implementing a university-wide strategy for engineering entrepreneurship from 2009. The strategy is based on two main pillars and covers curricular and extra-curricular activity. The essence of the strategy is to involve youngsters in entrepreneurial education. It prescribes that 100 % of university students gain the basic knowledge of entrepreneurial and innovative activity during the 2nd and the 4th year of their programmes in the Entrepreneurship and the Engineering Entrepreneurship courses respectively. For those who wish to further their knowledge between the two courses, they may opt for two educational minors with fundamentally different sets of disciplines:

- Technological Business (TIPS, innovative marketing, project management);
- Intrafirm Business (lean manufacturing, quality management, logistics).

All courses are aimed at developing softskills, which are considered of high importance in training successful entrepreneurs at technical universities, e.g. communication skills, leadership, time management, planning, teamwork, emotional intelligence. Besides, TPU hosts up to 30 extra-curricular events annually each serving one of the three different purposes:

- Inspire - to inform students about business possibilities;
- Engage - to support first student's entrepreneurial initiatives;
- Accelerate - to develop student's projects into start-ups.

Such events usually involve about 10 % (~1200) university students where 3 % of participants start their own new business. The establishment of the School of Engineering Entrepreneurship in 2017 was an important milestone in the TPU entrepreneurship strategy. The School facilitates innovative and entrepreneurial projects across university divisions. The aim of the School is to form an entrepreneurial ecosystem inside and around TPU, which develops according to the open innovation model. This ecosystem produces crossuniversity and interdisciplinary student teams that work together towards innovative projects under the mentorship of about 30 professional entrepreneurs. The TPU ecosystem attracts independent financing into student projects in the amount of over €125,000 per year.

PILLARS OF GLOBAL OPEN INNOVATION

Universities network with other universities and companies in order to exploit opportunities coming from research, integrate different knowledge sources, provide access to a vast range of contacts and open the door to international value chains and international impact.

On the one hand, research and innovation have a regional dimension, where agglomeration plays a role in creating positive externalities. However, research and innovation activities, being inherently collaborative in the age of globalisation and global networks, are also inherently global, including with regions outside the Europe. The three goals set by the European Commissioner for Research and Innovation Carlos Moedas during his mandate - i.e. Open Science, Open Innovation and Open to the World (European Commission, 2016) - cannot be understood separately. As Moedas mentioned when addressing the conference ´A new start for Europe: Opening up to an ERA of Innovation´ in Brussels in 2015, "new knowledge is created through global collaborations involving thousands of people from across the world and from all walks of life". The EU, United States, South Korea and China rival each other in international co-publications, however, despite the increasing internationalisation of technological collaborations, compared to the US, Europe is not taking full advantage of its international networks. To address this, the Commission has put forth a strategy of openness to the participation of entities outside Europe, through the primary vehicles of the EU Framework Programmes (FP) for Research and Innovation and the European Fund for Strategic Investments (EFSI).

This is a changing paradigm. Regardless of political momentum, the importance of remaining competitive at the global level, on one hand, and addressing global societal challenges, on the other, is here to stay. Scientific knowledge and technology will continue to circulate increasingly freely, via researcher mobility, via electronic communication and through papers, patents and other codified knowledge tools. Therefore, it is imperative to maximise Europe's capacity "to attract and retain the best researchers, boost competitiveness, support market uptake through confidence building, and encourage future cooperation with global research partners" (European Commission, 2016, pp. 68).

S&T universities are the best-positioned entities in this respect. When analysing which factors explain the reasons for firms' decisions to relocate their R&D activities outside or within the EU, a study reveals that "the quality of R&D personnel and access to network knowledge (with firms, universities and public organisations) are the most important factors for locating R&D activities in a given region or country. Public support for R&D appears to be relegated to a secondary position in the decision to locate R&D activities" (Cincera and Santos, 2017). This clearly emphasises the importance given to providing strong and sustainable regional and national innovation systems in Europe, around anchor institutions capable of bridging with all stakeholders to mobilise knowledge, talent and funding.

Moreover, knowledge-intensive foreign direct investment decisions are heavily influenced by the pool of skilled human resources available in a certain region, as well as the research and innovation infrastructures made available.

On the other hand, universities present a strong, knowledge-intensive, networking capacity at the global level and in a multidisciplinary nature, which is not possible for a private company or any other type of institution that operates in complete market rules and culture. Universities are key entities in pulling private firms in every region in Europe towards internationalisation. They do this through teaming up and building consortia for the European FP projects and networks, but also outer Europe, taking advantage of their external networks, collaboration agreements, protocols and personal contacts. Networking, sharing and internationalising is part of the S&T university DNA.

It is, therefore, crucial that future investment attraction policies become more inclusive of S&T universities and we underline the importance of really opening up future knowledge-intensive research and innovation funding programmes to global participation.

POLITÉCNICO DI MILANO (POLIMI)

Politecnico di Milano Chinese Campus (Politong) - established in 2011 - has two main objectives:

1. develop PoliMi´s research and educational activities in China;
2. collaborate with the best Chinise universities to organise activities aimed at the creation of a cooperation platform for technology development and exploitation.

Tsingua University Agreement TUS Holdings Limited: The ChinItaly Challenge favours teams composed of both Chinese and Italian members to stimulate cross-boundaries collaborations. The challenge focuses on original innovation, encouraging SME and start-ups to carry out cooperation aimed at boosting industrialisation and product development and to encourage outstanding projects to land in innovation incubators or technology parks in China and Italy.

Hong Kong Sof Landing Programme: A Hong Kong-based platform for start-ups, spin-offs and research teams from renowned overseas science parks, TTO, R&D institutes, incubation centres and spin-off/start-up companies to promote their innovations and technology to Hong Kong industry. Hong Kong Science & Technology Parks Corporation (HKSTP) offers a full range of support and resources to assist in exploring new business opportunities in Hong Kong as well as mainland China. The programme selected 24 technologies from Politecnico di Milano, and six Professors and the Head of the Technology Transfer Office have visited the Science Park and presented their innovations to investors and industries, boosting new collaborations.

UNIVERSITY OF STRATHCLYDE (STRATHCLYDE)

Nanyang Technological University (NTU) is one of Strathclyde's International Strategic Partners, starting from a framework collaboration agreement signed in 2013, and followed up by a number of successful researcher interactions and two annual Strathclyde/NTU/Industry Symposia, led by Strathclyde's Principal, Professor Sir Jim McDonald, Senior Advisor and Former President of NTU, Professor Bertil Andersson, and NTU Vice-President Research, Professor Lam Khin Yong.

Collaboration between the universities has developed particularly around their mutual bilateral relationships with Rolls Royce on electrical propulsion systems; and with GSK on pharmaceutical manufacturing. In 2017, both universities invested in a cluster of more than 20 PhD students to help underpin the establishment of sustained long-term engagements. Industry partners are involved with some of the Singapore PhDs being part of the Rolls-Royce@NTU Corporate Lab, and the paired PhDs linked to the Rolls-Royce University Technology Centre at Strathclyde. For Rolls Royce, the collaboration enables them to increase the strength of their university collaborations around a single technology roadmap. For the universities, the collaboration enables researchers to write joint articles and access new research funding.

Collaboration around pharmaceutical manufacturing is progressing similarly, and enables Strathclyde to access greater international expertise for the new industry pilot plant at the Medicines Manufacturing Innovation Centre, (see the Strathclyde Case Study), showing a ´global to local´ innovation impact within Scotland's new Advanced Manufacturing Innovation District.

CONCLUSIONS AND RECOMMENDATIONS

In this chapter, conclusions and recommendations to policy-makers, funders and universities are presented.

This white paper demonstrates that innovation ecosystems consist of many interacting players alongside universities and that both funding policy and institutional policy need to adapt, acknowledge and promote a multi-actor non-linear perspective to research and innovation. It identifies and illustrates through case studies, the important activities and role of S&T universities as innovation leaders. S&T universities' uniqueness lies in their capacity to bridge between S&T education, research and innovative capacity, providing the human resources and skills, the facilities and funding, the networks, and importantly the scale and leadership to act as regional and national innovation systems integrators.

Concretely, our Members provide dedicated services across seven dimensions:

1. business support, networking (i.e. sponsorship);
2. access to research and innovation infrastructures;
3. skills and competencies for technology development and support to start commercialisation;
4. funding support (e.g. Proof of Concept schemes);
5. entrepreneurship education;
6. long-standing and international collaboration with industry and business;
7. ecosystem leadership & coordination (system integrators).

They, given their multidisciplinary nature, are well positioned to support and collaborate with their ecosystem, especially when new technological paradigms are emerging. However, this opportunity cannot always be fully realised due to constraints that limit most universities' efforts regarding (open) innovation:

- funding is limited, especially for early and middle stages of technology development;
- existing financial incentives are not enough to promote growth;
- universities must be able to act autonomously and be able to deploy physical, human and monetary assets in an agile way to support the development of the ecosystem, something which is not possible in many countries in Europe.

This engenders a *de facto* limitation of the European capacity to overcome its difficulties in translating the excellent knowledge to the market. As demonstrated by the case studies and the data collected, S&T universities are innovation ecosystems integrators and crucial actors in organising the innovation system, connecting stakeholders and translating technologies into economic value. The following conditions need to be met:

1. S&T universities must do more to create critical interdisciplinary mass to address innovation challenges, through internal growth and organisational change, through regional and national collaborations and using international networks.
2. Excellent university leadership linking all quadruple helix organisations - from SME to large industry, public services and government, other private for profit and not-for-profit organisations is crucial. This leadership and integration capacity must be acknowledged and translated into funding instruments. In particular the traditional "Third mission" must be broadened into a "Mission 3.1" where universities not only interact with other knowledge

partners, but actively develop, coordinate and integrate the ecosystem, bringing in new partners and filling critical gaps.

3. Innovation ecosystems and emergent supply chains are boosted through co-location of a critical mass of business, industries, SME, public services and citizens in related sectors and assurance of absorptive capacity of talent in the labour market. Recently the traditional cluster, science park and incubator concepts have broadened towards innovation districts, networks and innovation hubs as models for co-location.
4. With increased specialisms in technical competences, greater national and transnational collaborations between regional open ecosystems are needed to develop internationally competitive emergent supply chains.
5. Creativity, innovative minds-sets and a vibrant start-up scene are key to provide the energy needed to maintain a healthy innovation ecosystem.
6. Alongside technological innovations there is a corresponding need to identify opportunities from business model and regulatory innovations.
7. There is a continuing need to attract and leverage private and public money streams, carefully designing governance structures and achieving a critical mass in risk and venture capital funds.

RECOMMENDATIONS FOR POLICY-MAKERS AND FUNDERS

- Public sector funds need to deliver more early stage and Proof of Concept schemes. Universities have very little access to funding for proof of concept due to limitations in eligibility arising from the ingrained mentality of a linear model of innovation;
- Flexible and simplified funding: Simplify, ensure synergies between European and national or regional public funding instruments for research and innovation;
- Funding structures must support more bottom-up, high-risk, emerging and breakthrough science and technologies with leading researchers working in an `open innovation context` ensuring that there is greater space for emergent supply chains;
- Create diverse risk and venture capital funds (within the remit of State Aid & Competition rules) at European, national and regional levels, allowing for Framework Programme rules to be applied at all levels;
- Create effective tools and mechanisms to allow for top-up funding of costs at universities, and the innovative blending of grant, loan and equity-based forms of investment;
- Support should aim at the investment of large-scale block grants for the ecosystem integration role to be co-invested with other private and public sources, and aimed at stimulating new initiatives to ensure the long-term sustainability of the ecosystem;
- Funding instruments should require the establishment of an effective assessment system for the `health` of an ecosystem based on multiple factors, e.g. start-ups, growth, acceleration, retention of talent, through adaptive approaches designed to recognise open ecosystem strengths and weaknesses;
- Evaluation should be carried out in ways that enable the evaluation of quality in innovation systems to stimulate appropriate risk-taking, and to avoid a box-ticking mentality. For example, direct interaction between evaluators and proposers (interview) before completion of evaluation reports should be organised, allowing for clarification of questions and verification of information.

RECOMMENDATIONS FOR UNIVERSITY LEADERS

- Drive organisational change to ensure the university can collaborate effectively with external partners:
    - Benchmark, network and learn from other universities that are already driving their ecosystems, by using the appropriate fora, such as CESAER task forces;
    - Develop effective management and incentive structures to ensure that technology transfer, knowledge exchange, and science-based entrepreneurship is valued across different departments, faculties, and RII;
    - Create networks comprising of diversified actors (idea generators, incubators, finance, marketing etc.) that allow your university to enhance the entrepreneurial ecosystem.
- Focus on developing innovation skills and awareness in staff and students:
    - Focus training for undergraduates on sensitisation to entrepreneurial and innovative thinking. For (post-)graduate students and academic staff the focus should be challenge-led and outcome-driven;
    - Train staff to identify and encourage entrepreneurial, innovative and inventive mindsets, and to foster peer-learning amongst students;
    - Train researchers how to maximise the impact of their research;
    - Promote creative-thinking and sharing of multidisciplinary perspectives, especially between STEM and SSH;
    - Incentivise high-level exchanges between universities and industry, including measures to attract highly innovative industry professionals to join academia, in order to provide innovation leadership.
- Go beyond participation in the innovation ecosystem (Third Mission) to actively enhance the innovation ecosystem (“Mission 3.1”)
    - Develop specific activities to engage industry partners and other organisations, seed creativity and entrepreneurship and position the university at the centre of the ecosystem through open and collaborative leadership;
    - Establish collaborative spaces that stimulate the interaction of students, researchers, industry and societal actors;
    - Become an active investor in early stage companies, in collaboration with others.
    - Further open RII to the ecosystem. Ensure a culture of openness and proactive collaboration and service to industry and society;
    - Use universities’ national and international links to benefit other actors in the ecosystem, and to attract players from outside the regional ecosystem;
    - Organise teaching and research activities so that they provide multiple spin-off benefits to other actors in the ecosystem;
    - Work with industry to identify future skills and technology needs, and invest in these areas within the university;
    - Identify gaps in the innovation ecosystem – for example, in industrial partners, skills, innovation infrastructure, finance, - and work with partner organisations to fill these gaps.

ANNEX I: ABBREVIATIONS

ABBREVIATION	MEANING
AFRC	Advanced Forming Research Centre
BIP	Business Ignition Programme
DG RTD	Directorate General for Research and Innovation of the European Commission
EC	European Commission
ECTS	European Credits Transfer and Accumulation System
EIC	European Innovation Council
EIF	European Investment Fund
EIT	European Institute of Innovation and Technology
ERA	European Research Area
ERC	European Research Council
ESIF	European Structural and Investment Funds
EU	European Union
FP	EU Framework Programme for Research & Innovation
GCID	Glasgow City Innovation District
HKSTP	Hong Kong Science & Technology Parks Corporation
IP	Intellectual Property
IT	Information Technologies
JRC	Joint Research Centre
Lcie	Leuven Community for Innovation driven Entrepreneurship
MOOC	Massive Open Online Course
MoU	Memorandum of Understanding
MS	EU Member State
NTU	Nanyang Technological University
NTNU	Norwegian University of Science and Technology
PhD	Doctor of Philosophy
PoC	Proof of Concept
PoliMi	Politecnico di Milano
PoliTo	Politecnico di Torino
RII	Research & Industrial Infrastructures
RRI	Responsible Research & Innovation
RTO	Research and Technology Organisation
R&D	Research and Development
R&I	Research and Innovation
RWTH Aachen	RWTH Aachen University
SME	Small and Medium Enterprise
SSH	Social Sciences and Humanities
STEM	Science, Technology, Engineering & Mathematics
S&T	Science and Technology
Technion	Israel Institute of Technology
TF	Task Force
TIC	Technology and Innovation Centre
TIME	Top Industrials Managers Europe
ToR	Terms of Reference
TPU	Tomsk Polytechnic University
TRL	Technology Readiness Level
TTO	Technology Transfer Office
TU Delft	Delft University of Technology
UN SDGs	United Nations Sustainable Development Goals
UPC	Universitad Politecnica de Catalunya
UPorto	University of Porto

ANNEX II: LITERATURE LIST

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