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How Universities Contribute to Innovation: A Literature Review-based Analysis

NTNU
Norwegian University of Science and Technology

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CLIENT
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CLIENT'S REF.
This report is the second of NTNUs planned responses to the request from the Norwegian Ministry of Education and Research to establish a better and more detailed knowledge-base about the impacts of NTNU's overall activities on innovation on Norwegian economy and society. *First response: Towards a better system for measuring the contribution of the UoH sector to Innovation. (NTNU March 2019)*

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Contents

NTNU's comments on the report, how can we use this knowledge base for the further development of Norwegian universities?

Based on the content of this report, I would like to share my thoughts about how Norwegian universities in general, and NTNU in particular, may relate to this analysis. The background of this report is an assignment given by the Norwegian Ministry of Education and Research to NTNU. The objective was to investigate how universities contribute to innovation in both the private and public sectors. The report identifies key contributions to the scientific literature, and summarizes the main findings.

One important conclusion from this independent scholarly work is that universities contribute to value creation and impact in society through several innovation channels. The most important channels identified in the report are through direct research collaboration with industry and the transfer of knowledge and technological solutions within research centers. In these centers, private and public sector are collaborative partners with the universities, and student-led innovation and education are frequently included. As Pro-Rector for Innovation, I am proud that NTNU for several years now has prioritized and meticulously developed our innovation ecosystem through these important channels.

Future Education and Knowledge Needs for fulfilling Innovation in the Private and Public Sectors

Norwegian universities and university colleges have a pivotal role to play in the challenging restructuring process that the Norwegian economy is undergoing. New knowledge and skills, the ability to develop and exploit new technologies, as well as understanding how technology and society interact, are all critical success factors that universities can contribute to in this ongoing process of change. In addition, sustainable development is an imperative for our future, with a sustainable development path presupposing groundbreaking innovations in the years to come. We need to experiment more across disciplines and sectors in our search for new and more effective ideas for a sustainable future.

Universities must continue to develop their *educational* programs, so that graduated students are able to meet and deal with the modern societal needs. This is the reason why NTNU has started our work with developing "next generation education programs" within technology, the humanities, social sciences and health. In addition, NTNU is further developing existing and preparing new courses within lifelong learning, as both the private and public sectors have requested so many times due to tremendous demands. Rendering university education more pertinent for Norwegian society is the primary objective of a forthcoming white paper on employment and work relevance in education. Our society needs competent employees who take initiative, cooperate across

disciplines, adapt quickly to new situations and solve complex challenges in a digital and sustainable economy. The ability to make use of new and future technologies, such as robotics, automation and digitalization, will be an important competitive advantage and crucial for success in a world of globally competitive markets.
In this context, the development of *entrepreneurial and intrapreneurial competencies* in our education is becoming increasingly important. The report highlights that these competencies can only be developed in a dynamic innovation ecosystem where universities, the private sector and the public sector work together. The need for innovation and reorganization in the public sector is also clearly articulated in the forthcoming white paper on innovation in the public sector. There are relatively few research and innovation policy instruments designed with the objective to encourage knowledge development between universities and the public sector. This report emphasizes the need for more experimentation, creativity, openness and systematic work from the public sector and universities. The report also points to the untapped potential within the humanities and social sciences. There are several examples in which contributions from the humanities and social sciences led to clearly improved public sector products and services.

Research Collaboration as a base for innovation

NTNU is experiencing an increasing demand for R&D collaboration from both the private and public sectors. In combination with university research excellence as a key factor for a high university innovation impact, the literature emphasizes the importance of geographical and relational closeness between industry and university researchers. In Norway, there are several good examples of policy instruments enhancing knowledge collaboration and transfer both ways between the business sector and academia, in particular, university-industry research centers, such as the *Center for Research-based Innovation (SFIs) and the Centers for Environment-friendly Energy Research (FMEs)*. These centers develop long-term relationships and deliver new knowledge, competence, prototypes, new methods, new technologies, new employees and innovation solutions to their partners and to the broader society. In these centers, students, academics, firms and end-users all collaborate to solve specific applied research problems. These types of university-industry collaborations will also be a key asset for a successful Norwegian participation in the future EU Framework Programs for Research and Innovation. In the new *Horizon Europe* program, there is an increased focus on economic and societal impacts, on societal missions and on research excellence.

The present report provides evidence for the fact that a long-term focus on research quality is an essential prerequisite for a high university innovation impact. We therefore need to keep up our efforts for research excellence along the entirety of the TRL scale (TRL - Technology Readiness Level), which requires a close and long-term collaboration between academia, research organizations and the private and public sectors.

Norway needs to improve further research excellence, while simultaneously focusing on research collaborations of high impact with both the private and public sectors. As pointed out in the literature, several scholars mention different types of challenges related to close collaborative interactions between academia and the business sector. These challenges must be recognized and mitigated so that collaboration culture can flourish. Nevertheless, there are many examples of successful collaborations. The winner of the Norwegian Research Council's (RCN) "Innovation Price 2019" is a good example of a successful university-industry research center collaboration and excellence in research.

That being said, at a micro-level the report identifies a knowledge gap in the literature about how most effectively to deal with the challenges emerging within university-industry collaborations. In particular, we know little about good policies and managerial practices to help alleviate non-productive tensions and conflicts. However, it is well documented that long-term collaborations tend to reduce tensions and increase mutual benefits between the collaborating partners.

Academic entrepreneurship and the new business sector

Academic entrepreneurship, university spin-offs and student entrepreneurship are important innovation channels, but they still only constitute a small part of universities´ overall innovation contribution to society. Yet, one may question why the numbers of academic patents and academic spin-offs are not larger despite the fact that universities carry out applied and strategic research for billions of NOK every year. International capital- and investment communities show an increased interest in Norwegian universities. This is an indication that Norwegian universities have a greater potential for academic entrepreneurship and commercialization than that being explored so far. However, neither the university sector itself, the Norwegian capital community nor national policy instruments seem to be powerful enough to unleash this potential. One lesson from this report is that universities must experiment with new initiatives to a greater extent, thereby connecting their various innovation activities into a more coherent university ecosystem logic playing with and integrated with the ecosystem outside the academia and within the industry and public sector. NTNU has been proactive in this by supporting many different related initiatives, among others, initiatives promoting student-driven entrepreneurship like START and Spark. For example, we hope that the NTNU's School of Entrepreneurship, with its innovative, high-quality master program on entrepreneurship, may provide some new ideas to other universities. We also hope that our centers of educational excellence will keep carrying out research on practices and methods for an increased innovation impact across all disciplines.

Another area where we need to intensify our efforts is to increase the innovation impact of the SFI and FME activities that NTNU participates in. With this as its objective, NTNU established a Strategic Program for Research-based Innovation. This program funds new innovation managers who will work closely together with NTNU researchers to increase the innovation output of our research, especially research conducted in university-industry centers. In addition, the program is aiming to increase innovation competence and improve innovation culture within the university as well as making it easier to collaborate with NTNU.

Furthermore, several Norwegian universities are experimenting with new funding initiatives of student-led entrepreneurship, such as NTNU Discovery and SPARK Norway (University of Oslo). These initiatives have as their goal helping students and employees to transform their initial innovative ideas to more mature innovation project propositions that can be taken further toward a commercialization phase by the Technology Transfer Offices (TTOs) and/or the private sector. NTNU now stimulates responsible innovation at all levels, and is taking actions to enable our employees and leaders to deliver on innovation, in addition to other core activities such as teaching, research and the dissemination of research results.

Highlighting the contributions from universities

The initiatives and activities for promoting innovation and value creation adopted by NTNU are not necessarily suitable for other universities. One should not uncritically adopt innovation strategies and practices from other – even world-famous – universities, since these "role model universities" often operate within different ecosystems and have different ownership and funding structures compared to the Norwegian universities. Having said that, Norwegian universities can certainly learn quite a bit from excellent international university innovation practices and ecosystems. The important point to make here is that each institution must develop its own realistic strategy on the basis of the strengths and opportunities in their innovation channels, on the basis of their networks at regional, national and international levels and on the basis of their collaborative history with the business and public sectors.

We must also learn to better document and communicate how universities create value in our societies. This is becoming a prerequisite for obtaining research funding, both within the EU's Research and Innovation programs within national research, and with innovation policy instruments. The ability to systematically think about the innovation impact is a key skill for the researchers of the future.

Based on this analysis, NTNU and I, as Pro-Rector, will focus on more research-based innovation and student entrepreneurship to help benefit society. In addition to experimenting with new initiatives at NTNU, I will work to ensure that our researcher communities continue to contribute to knowledge for a better national policy, and to a more efficient and adaptable business and public sector regionally, nationally and internationally.

Trondheim, November 25th, 2019
Toril Nagelhus Hernes, Pro-Rector for Innovation, NTNU

Preface

In 2018, the Pro-Rector of innovation at the Norwegian University of Science and Technology (NTNU), Toril A. Nagelhus Hernes, established a project group consisting of four faculty members, all from NTNU, with the objective to investigate what we know about how Higher Education Institutions (Universities) contribute to innovation processes in the Norwegian economy and society. The four appointed faculty members of the project are: Arild Aspelund, Aris Kaloudis, Øivind Strand and Roger Sørheim. Aris Kaloudis was the project coordinator.

The project represents one of the first steps of NTNUs strategic commitment to establish a richer knowledge base about the impacts of NTNU's overall activities on innovation in Norway, with a particular emphasis on the activities related to NTNU's participation in university-industry collaborations (UIC) and in university-industry research centres (SFIs and FMEs).

Consequently, the research project commissioned by the Pro-Rector has as a main objective to establish a *knowledge base on what measures and organizational tools seem to promote innovation from the universities*. The mandate of the project provisions is that the study should also include:

1. A *state of the art* analysis consisting of:
- A summary of published scientific knowledge of what promotes innovation from the university sector/how universities contribute to innovation in existing business and public sectors, and new business.
- Summarize the literature regarding the connection between the university's educational portfolio (innovation in education), research activity and focus on entrepreneurship, including tools for translating research into practical utility/innovation/entrepreneurship among both students and employees. What does state of the art say about "best practice"?
- Knowledge on the impact of academic innovation must be mentioned

2. The study should summarize documented knowledge of how innovation takes place in *research centres and clusters,* and what promotes innovation from these.
3. Knowledge of innovation in collaboration between the university and external actors, including actors from both the business- and public sectors.
4. Discuss state of the art in conjunction with status and practice in Norway and Norwegian universities, policy design (Industry Report, LTP, Research Council), etc.
5. The study should provide some advice on how it is possible increase the innovation impact of Norwegian universities.

This report is the result of the research project that complements the work published in the NTNU report, "Mot et bredere målesystem for UoH-sektorens bidrag til Innovasjon: Forslag til målesystem basert på erfaringer fra NTNU", in which indicators measuring universities' contributions to innovation are discussed and evaluated. Therefore, in this report we do not review the vast amount of literature on how we measure academic-based innovation activities and their impacts.

The following authors contributed to the chapters of the report:
Aris Kaloudis, NTNU: Chapters 1, 2 and 8
Thomas A. Lauvås and Øivind Strand, NTNU: Chapter 3
Thomas A. Lauvås, Nord University: Chapter 4
Marius Tuft Mathisen, NTNU: Chapter 5
Torgeir Aadland NTNU: Chapter 6
Per M. Koch, Nordic Institute for Studies in Innovation, Research and Education (NIFU): Chapter 7
Arild Aspelund, Aris Kaloudis, Øivind Strand and Roger Sørheim (all NTNU): Chapter 9

The authors have been selected by the project team on the basis of their fields of expertise and previous knowledge, in addition to publications on the specific topics they discuss in their respective chapters.

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1. Objectives and thematic directions of this report

In all advanced economies, Higher Education Institutions (HEI) are expected to play a key role in promoting innovation, entrepreneurship and structural change (Perkmann & Walsh, 2007; Ankrah & Al-Tabbaa, 2015). The increasing population shares of university-educated, the economic importance of knowledge-intensive activities, the digital transformation sweeping across all organizational boundaries of the globe and the need to quickly forge efficient and innovative solutions to address pressing societal challenges, are just some of the reasons explaining why universities are expected to deliver more and better on their third mission, i.e., the demand to contribute more to innovation and to economic and societal change. This new type of "social contract" with universities begs the question of: *What do we know about how modern Universities contribute to the various forms of innovation and entrepreneurship in the diverse economies of the 21th century?* This is the key research question guiding the analyses in this report. The main objective of the report is to establish a state of the art, based on an analysis of published scientific papers on how universities contribute to innovation.

The primary motivation behind this report is to produce knowledge that permits the asking of more precise and specific strategic questions about what type of actions are most likely to further improve the innovation performance of Norwegian universities, given the distinctive features of the Norwegian innovation and educational system. Is there potential for increased academic innovation activity in Norway, and towards which direction? What types of impacts should we measure and document more carefully? Is it advisable to reshape academic incentive systems and operational modes in order to boost more innovation? What are the new opportunities and the new challenges demanding better and more academic innovation activity? These are some of the policy questions that motivate our analysis.

1.1 Types of innovation impacts and universities

Several prevailing and persistent factors determine how universities contribute to innovation and entrepreneurship. New goals and directions in regional, national and international *R&D and innovation policies*, as well as educational policies, are of an example of a *policy trend* with profound effects on how universities deliver knowledge, skills and services for innovation and entrepreneurship.

There are several channels through which universities contribute to innovation processes. Some of these channels are purposefully and selectively developed by universities themselves or by policy design for that reason. Academic start-ups, academic patenting, student-based entrepreneurship, education programmes for innovation and entrepreneurship, in addition to a multitude of policy measures funding collaboration between Universities and the private and public sectors, are examples of channels/activities assumed to have direct impacts on innovation processes. Others academic activities, however, represent more oblique channels, and may have indirect effects on the capacity and capability to innovate in the economy. University graduates and their skills, participation in scientific and/or practitioner conferences, scientific publications, popularization of science and technology activities, academic participation in committees and policy processes, and of course, the myriads of informal communication channels and networks between academics, industry and the broader society, are all examples of processes that may have a considerable effect on the trajectories of innovation processes; yet, they impact innovation through "serendipity", rather than through a purposeful, organized and targeted organization of knowledge interactions for innovation.

In this report, we delineate our investigation only to those channels that work more directly on economic and societal innovation processes. This does not mean that other core academic activities, such as teaching, researching and debating, are not important for our societies. On the contrary, some of the indirect/informal channels may have a much deeper and long-lasting effect on our culture and political systems, and on our future, than the direct channels. Even so, a discussion of the impacts of these broader, and less targeted activities on innovation, must be left to another report.

Below, we shortly introduce the main innovation channels this report is focusing on:

University–industry collaborations (UICs), university-centred clusters and university-industry research centres, represent a major channel through which Universities contribute to technological development and innovation directly to the involved collaborating companies. And more indirectly, via sequences of knowledge spillover loops, they often also have an impact far beyond the network of university-collaborating firms.

Academics are increasingly directly involved in the commercialization of their research, either by starting new firms or patenting/licencing technological solutions or technology platforms. It is still unclear how economically important these forms of *academic entrepreneurship* are. There is evidence in the scientific literature in many countries and many regions that the direct effects of academic spin-offs (ASOs) seem not to be that important. Nevertheless, there are wider effects from such ASOs or from academic patenting – even for those that do not succeed. There is an increasing understanding that even failed spin-offs provide a mechanism for diffusing and exploiting knowledge that benefits other entrepreneurs, facilitates the expansion of firms and strengthens the competence structure of supporting actors and sectors.

University graduates represent a huge potential for stimulating innovation and entrepreneurship, either by directly establishing their own firms or through their employment. Preparing these students for careers in increasingly innovation-intensive working environments and helping them to acquire skills enhancing their entrepreneurial and intrapreneurial abilities, are one of the tasks for Universities that only recently are being fully recognized.

Universities also engage with a large array of activities of importance for enhancing productivity and *innovation in the public sector*. Although there has been an increasing number of publications contributing new knowledge on this topic over the last few years, there is still limited knowledge on the nature and quality of these interactions. Yet, both in the private and public sectors, innovation often assumes the form of co-learning and co-production in ecosystems, in which universities play an important systemic role.

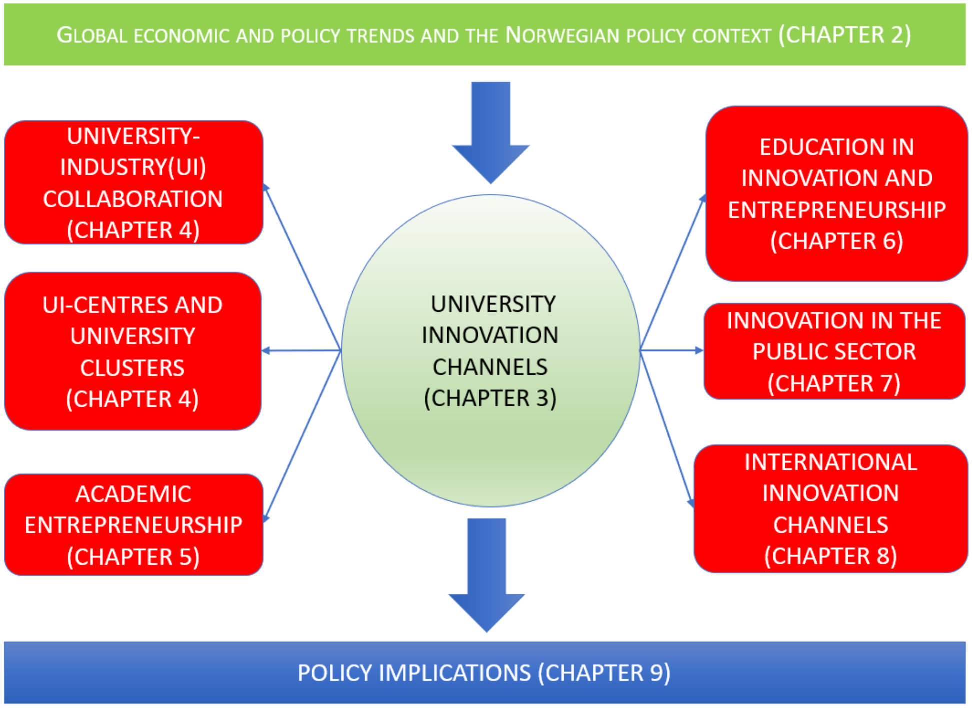
Universities are also expected to play a more international innovative role in providing ideas and developing technologies in order to cope with major societal challenges, such as the 17 *sustainable development challenges* (SDGs) defined by the United Nations (UN). Universities have a key role to play in delivering solutions that can help countries in their efforts to tackle many of the SDGs such as a climate change, cleaner environment, global public health and poverty reduction.

1.2 The contents of the report

The discussion above leads directly to the thematic structure of the report:

- Chapter 2 places Universities within a broader international socio-economic and policy context, and identifies the most important policy trends directly affecting Universities' incentives and capacities for innovation.
- Chapter 3 provides an overview of the literature identifying the types of innovation channels available to Universities and discusses the relative importance of these channels as vehicles of innovation impacts. Based on the discussion in Chapter 3, each one of the following chapters (Chapters 4-8) focuses on the channel with the largest significance and impact.
- Chapter 4 directly targets one of the Universities' chief innovation impact channels, namely university-industry collaboration (UIC) in R&D projects and, in particular, university-industry research centres. The chapter provides an outline of the scientific literature in this topic, and discusses factors determining the innovation impacts of these collaborations.
- Chapter 5 reviews the literature of academic entrepreneurship in general, and addresses the question of what we know about the impact of academic spin-offs.
- Chapter 6 focuses on publications that study the impact of Universities' educational activities, targeting the advancement of innovation and entrepreneurial skills of students, as well as the impacts of different aspects of student entrepreneurship.
- Chapter 7 analyses the scientific literature, studying how Universities contribute to innovation in the public sector.
- Chapter 8 identifies and summarizes literature on how Universities contribute to innovation beyond regional and national borders. The chapter also investigates what are the main international arenas of research knowledge co-production in international networks of foreign firms and research institutions.
- Chapter 9 reflects on the findings in Chapters 2-8 and provides policy implications based on those findings.

Figure 1.1: The structure of the report



1.3 Methodological notes on the thematic scope

The literature addressing the research questions we investigate is immense. We do not claim that the report provides a systematic literature review of all of this vast volume of literature, although we believe we comprehensively identified and summarized the most significant scholarly contributions and the state of the art on what we know about *how Universities contribute to the various forms of innovation and entrepreneurship*.

In our overview of the literature, priority has been given to more recent publications – especially review papers of high quality. We only focused on the literature of innovation impacts linked to universities, disregarding the equally vast literature studying the universities as organizations, i.e., their funding sources, governance of Universities, inflow of human resources, research mobility and even incoming knowledge flows.

Furthermore, the links between Universities' impact on microeconomic innovation dynamics and patterns of macroeconomic growth are, unfortunately, neither well conceptualized nor adequately modeled. Mapping this analytically fragmented terrain in a more rigorous and comprehensive analytical framework remains an analytical challenge, and is therefore placed outside the scope of this report.

There is also a vast amount of literature studying how specific scientific disciplines, e.g., Chemistry, Medicine, Engineering, etc. relate to the developments of new emerging technologies, such as ICT, biotech, nanotech, and how these technologies shape innovation in specific economic sectors, e.g., Pharmaceuticals. This report does not provide any systematic analysis of this literature.

Lastly, although there is a fairly large amount of literature about the regional impacts of Universities, we do not include a separate chapter on this issue. On the other hand, we review a large number of influential papers, and discuss this issue of regional impact in almost all the chapters of this report.

Bibliography

Ankrah, S., & Al-Tabbaa, O. (2015). Universities–industry collaboration: A systematic review. *Scandinavian Journal of Management,* 31, 387-408.

Perkmann, M., & Walsh, K. (2007). University–industry relationships and open innovation: Towards a research agenda. *International Journal of Management Reviews,* 9, 259-280.

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2. The broader context of university innovation impacts

The objective of this chapter is to highlight major global trends that shape the new roles Higher Education Institutions (Universities) play in modern innovation processes, and ultimately to structural change. We first discuss the implications the transition to the knowledge economy has on Universities. Universities increasingly need to directly engage in the co-creation processes of advanced knowledge in collaboration with firms and public organizations, or within university-industry research centres, in business clusters, in science parks or in innovation and entrepreneurial ecosystems. We then proceed with the presentation of three distinct innovation policy logics that articulate different kinds of incentives for Universities since World War II, with an emphasis on policy developments over the last two decades. In the last section, we briefly present the policy landscape of the Norwegian Universities.

2.1 The knowledge economy and its drivers

Over the last three decades, there has been an extensive scholarly effort to understand the inner dynamics of the "*knowledge economy*" (OECD, 2001; Smith, 2002). Firms in modern economies invest in a wider range of intangible assets, such as R&D, data, software, patents, designs, new organizational processes and firm-specific skills. Taken together, these non-physical assets make up knowledge-based capital[1] (OECD, 2013). Knowledge investments are economy-wide, not only confined to high-tech sectors, and not only confined to R&D. They are now greater in volume than tangible (i.e. physical assets such as buildings, machines, etc.) investments in all developed countries, and have become one of the prevalent features of modern economies (Haskel & Westlake, 2018). It is already from those introductory notes that the role of Universities in economies dominated by knowledge-based capital formation and knowledge-based economic growth cannot be underestimated. The question is exactly how Universities contribute to these developments.

Interactions with Universities in a knowledge-economy context

In addition to the issue of intangible investments, the notion of a "knowledge economy" also refers to the increasing complexities of managing and extracting value from the great variety of learning processes in R&D and production value chains.

Scientific and technological knowledge is *not* costless to transmit. A vast volume of literature from the field of innovation studies demonstrates that organizational ability to access and use knowledge often requires complementary skills, assets and prior experience, which implies a considerable and ongoing knowledge of investment commitments. This makes knowledge "sticky" and difficult to share and transfer. A key lesson from these studies is that the ability of an organization to capture and effectively use knowledge external to the organization (termed in the literature as organizational *absorptive capacity*) depends on being engaged in one's own knowledge creation and innovation activities. It is therefore

[1] One widely accepted classification groups KBC into three types: computerized information (software and databases), innovative property (patents, copyrights, designs, trademarks) and economic competencies, including brand equity, firm-specific human capital, networks of people and institutions, and organizational know-how, all of which increases enterprise efficiency (OECD, 2013).

difficult to free-ride on the creation of knowledge by others (Cohen & Levinthal, 1990).

The willingness and ability to build and promote absorptive capacities within firms on the one hand, and the breadth, quality and international range of the Universities on the other, seem to determine the types and intensity of interactions between Universities and economic agents. In particular, high levels of absorptive capacity in firms increase opportunities to search for- and engage in collaborative activities with Universities (Laursen et al., 2011). For example, Laursen et al. (2011) find that firms located close to a lower-tier university (in the UK) reduce the propensity for firms to collaborate locally, while co-location with top-tier universities promotes collaboration. Firms appear to give preference to the research quality of the university partner over geographical closeness. This is especially true for high-research and development-intensive firms.

Nonetheless, Fitjar and Gjelsvik (2018) find that (Norwegian) firms sometimes prefer to collaborate with local Universities, rather than with higher-quality universities at a distance. Firms' choices are not only based on the fact that knowledge transfer across distance is costly, but also that collaborating locally reduces the risk of information loss when the knowledge is transferred, as well as costs. There are also other reasons that could explain the observed collaboration patterns. For instance, if the local university can make a useful contribution, this may be considered as "good enough" from local firms. Firms may also see collaboration as a long-term investment, thereby helping to build research quality at the local university with the hope of reaping benefits in the future. Firms may also want to contribute to the local community by supporting the local/regional HEI.

The discussion above suggests that knowledge interactions with Universities depend on whether collaborating firms are embedded in the globalized knowledge economy, whether they have developed strategies and practices for their own learning and whether Universities themselves have the quality and ability to build and improve their teaching and research on the basis of external collaborations.

On the other hand, it is wrong to think of knowledge interactions between Universities and economic actors as an exclusively dyadic relationship phenomenon. There is a large body of literature showing that the *knowledge base* of any modern industry is not internal to (i.e. is not entirely possessed and contained within) any individual firm. It is not even internal to a group of firms or an entire economic sector. The knowledge bases are distributed across a range of technologies, actors and industries in modern economies (David & Foray, 1999). And this is precisely why the role of Universities is of strategic importance. Modern economic growth is not only based on the creation of new firms such as Google, Apple, etc. or on new economic sectors (i.e. ICT). It is also based on the internal transformation of extant economic sectors and their continuous technological and business model upgrading (Smith, 2002). Therefore, the capacity to transform and develop extant business models resides on complex "innovation and entrepreneurial systems" that create, process and distribute advanced knowledge. Understanding how these complex systems structure knowledge interactions in relation to Universities is critical. In the next sections we discuss two key concepts: the concept of (knowledge-intensive business) clusters and the concept of innovation ecosystems.

2.2 University-based clusters

Porter (1998, p. 78) defined clusters as: "*geographic concentrations of interconnected companies and institutions in a particular field*. Clusters [...] often extend downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies, or common inputs. Finally, many clusters include governmental and other institutions – such as universities, standards-setting agencies, think tanks, vocational training providers, and trade associations – that provide specialized training, education, information, research, and technical support". In the same paper, Porter argues that clusters are a prevalent feature of the globalized economy, and the reason they are prevalent is that they provide a form of regional "competitive advantage" by enhancing productivity (through specialization and low transaction costs), innovation and new firm formation within them. Some of the clusters Porter studied stem from commercialization ideas and companies based on university research, e.g., several clusters located in Massachusetts originating from research conducted at MIT and Harvard. Porter's message to policymakers is clear: "Governments should promote clusters formation and upgrading and the build-up of public or quasi-public goods that have a significant impact on many linked businesses" and he adds "[..] Universities have a stake in the competitiveness of local businesses" (Porter, 1998, p. 90).

Porter's ideas reverberated in national and regional policies, with a large number of OECD countries introducing cluster policy schemes from the 1990s onward. In Norway, for example, The Arena Programme was launched in 2002, the Norwegian Centres of Expertise (NCE) in 2006 and the Global Centres of Expertise (GCE) in 2014.

A lot of research has been done on business clusters since the seminal work of Porter in the 1990s. Important themes in this research are the study of different dimensions of proximity, lock-in trajectory situations, a related/unrelated variety of industries and technologies in clusters and, particularly after the recent economic crisis, factors that constitute more resilient regions and clusters (see for example Boschma, 2015), etc.

But what exactly do we know about the role of universities in business clusters and related science parks? Probably the best way to answer this question is to investigate how the EU conceived its cluster and regional policies. The EU developed an entirely new type of policy thinking and policy instruments, first based on the idea of cluster policies that evolved to the idea of knowledge-intensive clusters in the form of *Regional Research Intensive Parks* and *Science Parks* (European Commission, 2007) and gradually moving on to the ambitious Smart specialization platform policies (Radosevic, 2017). In all these Smart specialization policies, the role of science parks is essential, as it is mandatory that in the management of science parks universities participate in all important decision-making processes.

According to UNESCO[2] a, ''*Science and technology park encompasses any kind of high-tech cluster such as: technopolis, science park, science city, cyber park, high-tech (industrial) park, innovation centre, R&D park, university research park, research and technology park, science and technology park, science city, science town, technology park,technology incubator, technology park, technopark, technopole and technology business incubator.*"

[2] See: http://www.unesco.org/new/en/natural-sciences/science-technology/university-industry-partnerships/science-and-technology-park-governance/concept-and-definition/

The degree of involvement of Universities in the science parks varies across countries. For example, while all science parks in the UK are university initiatives (Siegel et al., 2003), in many other countries, including the US, Australia, Japan, France, Portugal, Spain and Italy, the degree of involvement of universities varies hugely. Albahari et al. (2017) investigated 25 Spanish science parks with 6,000 firms as tenants and more than 160,000 employees (in 2014). Albahari et al. (2017) identify four types of science parks: a) Pure Science Parks, in which the university is the major shareholder; b) Mixed Parks, in which a university is a minority shareholder; c) Technology Parks with a university, where there is no university shareholding, but where some university research facilities are located in the park; and d) Pure *Technology Parks*, in which universities have no formal involvement. The study found that pure science park firms show the highest patenting performance and lowest product innovation levels, while pure technology park firms perform best for sales of new to the market products and worst for patenting.

Another example of a relatively recent study of science parks is Minguillo and Thelwall (2015). This study analyses co-authorships (1975–2010) with organizations located in UK Science Parks in order to identify the role universities play. The main result of this bibliometric study is that most collaborations of firms in science parks are with off-park organizations, but that academic institutions are the primary source of knowledge and competence for on-park industries. Geographical proximity is a significant factor of research collaboration in science parks, but only in conjunction with the research quality of the knowledge source (i.e. the university). Furthermore, the same study finds that firms located in science parks mainly collaborate with external (off-park) partners because of the quality and relevance in the knowledge and expertise they can offer.

Another example of an interesting recent study from US science parks is Hobbs et al. (2017b). This study found that the distance between the science park and its university negatively affects the rate of employment growth of firms in the park. Hobbs et al. (2017a) also provide a comprehensive review of the literature from science parks. In summary, the overall evidence from this literature review converges into the conclusion that the proximity and research quality of the university in the relevant cognitive areas matter for the success (i.e. technological impact, economic growth and international recognition) of science parks. On the other hand, the carefully crafted study from Spain (Albahari et al., 2017) warns that university participation in science parks does not necessarily promote innovation as such (i.e. product innovation) among firm tenants.

Evaluations of the Norwegian Cluster Schemes

In 2016, Innovation Norway commissioned an official and comprehensive evaluation of 47 cluster projects in Norway, three Global Centres of Expertise (GCE), 15 NCE projects and 29 ARENA projects (Samfunnsøkonomisk Analyse AS, 2017).

The evaluation assessed: a) whether there is still a policy rationale for the cluster programme (i.e. if there exist market or systemic failures); b) Whether the cluster projects achieved their objectives and whether all the cluster projects together contributed to achieving the overall programme objective; and c) the quality of the management of the cluster programme. The overall objective of the three cluster programmes (i.e. GCE, NCE and ARENA) is to trigger a collaboration-based value creation that would not otherwise have happened, and to reinforce and accelerate the existing collaboration between cluster participants.

The evaluation did not particularly focus on the impact of Norwegian universities on the firms participating in the cluster projects. Having said that, the evaluation found clear evidence that collaborations between cluster firms in the same cluster have doubled in the Arena projects, and more than doubled in the NCE projects. There has also been a *significant increase in collaboration between cluster firms and R&D institutions in the same cluster project*, i.e. both research institutes and Universities (Samfunnsøkonomisk Analyse AS, 2017, p. 86).

The evaluation did not provide data allowing the direct measurement of whether cluster firms increased their innovation activities or not as a result of their participation in the cluster projects. However, the evaluation found an increase in the number of R&D projects with support from the Norwegian R&D tax credit scheme, SkatteFUNN, which is taken as an indication of an increase of the number of innovation projects generated by the cluster projects, and that cluster firms reported a significantly larger number of SkatteFUNN applications than other firms. The evaluation also found significant economic growth effects for the participating cluster firms.

For the three existing GCE projects, the evaluation has clearly shown that these projects are systemically important for the Norwegian economy since they involve a large number of cluster participants, and also contribute to the transition process away from oil and gas dependence. All three GCE cluster projects are closely linked to the rapid ongoing restructuring of the oil and gas sector.

Additionally, the scheme of Norwegian science parks managed by SIVA, a public enterprise owned by the Norwegian Ministry of Trade and Fisheries, has been evaluated, with the latest in 2015 (Jakobsen et al., 2015). Statistics Norway also produced a more quantitative analysis of the economic impacts of SIVA's activities in 2018. Neither of these two evaluation reports investigated in any detail what role the Norwegian universities play in the science parks (forsknings- og kunnskapsparker) or in Norwegian technology parks (Næringsparker). Investments in science parks by SIVA amounted to 48% in 2013, with both evaluation reports showing positive economic effects from SIVA activities.

Overall, these are quite positive results for the Norwegian cluster and science park policies, but there is still an open question as to whether universities should/can increase their impacts:

- on the economic value creation occurred in the cluster projects;
- on the quality and volume of innovation projects generated; and
- on the quality of research instigated by the collaboration between universities and cluster firms.

If we look back at the international literature, there is certainly much more to say in the future about the organizational forms and types of clusters and science parks, and the impacts of universities therein.

2.3 University innovation and entrepreneurship ecosystems

The notion of an ecosystem carries a very different set of connotations and implications than those of a "network" or "cluster". An ecosystem implies a complex, dynamic, emergent system that constantly adapts to its environment, sometimes in unexpected ways. Valkokari (2015) provides a conceptual discussion of the different uses of the concept of an "ecosystem" in conjunction with the concepts of "knowledge", "innovation" and "business".

The first use of the term *ecosystem* to describe a business environment can be traced back to James Moore, in his 1996 book, The Death of Competition. One of the first publications adopting the concept of *entrepreneurial ecosystem* was Isenberg (2010). Isenberg claims that "*The entrepreneurship ecosystem consists of a set of individual elements—such as leadership, culture, capital markets, and open-minded customers—that combine in complex ways.*" There are good reasons to claim why innovation, in general, and not only entrepreneurship, should be studied as an ecosystem phenomenon (Carlsson et al., 2002; Castellacci & Natera, 2013; Zahra & Wright, 2011). Autio et al. (2014) introduced the notion of *entrepreneurial innovation ecosystems*, understood as a set of interconnected actors that coalesce and respond to both policy and (macro)economic signals. All these publications underscore the role of universities as an important source of development of human, knowledge and entrepreneurial capital.

In the context of this report, there are several semantic advantages in adapting the notion of an "ecosystem" in the sense that it is commensurate with certain fundamental challenges universities face in dealing with the increasing complexity of innovation processes. These challenges are the following:

- The share of *international, collaborative and interdisciplinary* knowledge production is constantly increasing, thus posing challenges for traditional disciplinary academic research, which often depends on individual star researchers and their research groups. Interdisciplinary innovation is clearly more demanding to organize and manage.
- Increasing organizational and coordination complexity implies more systematic, even systemic, innovation approaches. The hypothesis is that individual academic spontaneity and an entrepreneurial spirit is not enough any longer.
- The nature of innovation knowledge exchanges is hence moving towards more complex patterns of knowledge co-creation and co-location (such as innovation clusters, multi-actor centres led by universities or the industry, public-private partnerships between government, industry and universities, etc.).

Innovation processes are - as we shall see in the next section of this chapter - broadening to include technological, social and economic innovation. It is claimed that universities have a central role to play here due to the breadth and depth of their research and education activities. The world is increasingly seeking systemic approaches to pressing challenges linked to topics like digitalization and sustainable development, which can only be addressed within a multiple actor perspective in interaction with each other and with their societal environments.

An important insight from the ecosystem literature is that in order for an organization, in our case this organization is a university, to survive and thrive, the key factor for success is to understand that *different forms of interaction are required in different ecosystems*. Top-down authority is usually not a prevalent future in socially constructed ecosystems. Yet, Valkokari (2015) claims that that knowledge ecosystems are not self-organized entities either: "*They are rather organizational designs that are* *held together on the condition that their members are in formal or informal agreement about shared purpose and operation modes (logic of action).*" Understanding the coordination mechanisms and their evolution over time is important, for one's own strategic decision-making and for influencing reformulations of a "shared purpose".

The entrepreneurial society
In a highly-cited paper, Audretsch (2014) shifts our attention to the broader implications of entrepreneurship as an emerging economy-wide, macro-phenomenon. For example, he argues that, "*As the economy has evolved from being driven by physical capital to knowledge, and then again to being driven by entrepreneurship, the role of the university has also evolved over time.*" In order to underscore this difference and make his point, Audretsch refers to another seminal paper by Etzkowitz (1983), who introduced the notion of both "entrepreneurial scientist" and "entrepreneurial university", claiming that, *"The entrepreneurial university integrates economic development into the university as an academic function along with teaching and research. It is this 'capitalisation of knowledge' that is the heart of a new mission for the university, linking universities to users of knowledge more tightly and establishing the university as an economic actor in its own right."*

On the other hand, in an entrepreneurial society, Audretsch (2007) and Audretsch (2014) argue that the role of the university is broader than just being an "entrepreneurial university". The key task of universities today is to create an *overall entrepreneurial thinking* and entrepreneurial capital in order to contribute to a dynamic economy and to an *entrepreneurial society*. In other words, modern universities need to facilitate innovation and entrepreneurial-driven economic growth through new organizational models, new curricula and new research programmes that are conducive to entrepreneurial activities in the society. The point is the development of innovation, intrapreneur and entrepreneur skills among students and academic staff, encouraging entrepreneurial culture and developing inter-relationships among groups of entrepreneurs, innovators, venture capitalists, business incubators, policy actors, etc. (Guerrero et al., 2016).

Yet, modern universities are themselves multi-faceted organizations. The increasing complexity of interactions between diverse innovation stakeholders and innovation and entrepreneurial arenas poses considerable *challenges*, in which differing objectives, cultures and norms co-exist in universities' organizational logics. With the need to embrace and interact in such complex open innovation ecosystems, universities are facing tensions in balancing traditional and new missions and tasks; as a result, the organizational models of universities are in a state of transition in many countries (Guerrero et al., 2016; Miller et al., 2014). Some of these tensions will be discussed in greater detail in other chapters of this report, yet it is important to mention here that there are concerns as to whether universities, especially universities in Europe, learn, adapt and reform themselves fast enough (Maasen & Olsen, 2007).

2.4 Trends in R&D and innovation policies and universities

R&D, innovation and higher education policies are shaped by the broader trends and perspectives presented above. For decades, the EU and OECD have been the international policy development hubs, instrumental for understanding national policy developments, including in Norway. It is possible to distinguish between *three broad waves of innovation policy paradigms* of pivotal importance for universities' engagement with their innovation roles: a) the linear science policy paradigm; b) the national and regional innovation system paradigm; and c) the transition policy paradigm. All three of these innovation policy paradigms co-exist in one form or another, thereby influencing current innovation policies in all advanced economies.

The linear model – science push

This policy paradigm of the 1950s and 60s understood innovation as an economic activity that directly builds on basic research breakthroughs and scientific discoveries. In short, scientific discoveries lead directly to innovations and economic growth. As such, capacity issues (i.e. the level of funding and the human resources of R&D in different scientific fields in universities, research institutes and in the business sector) were the primary concern of the policies of that period. The implicit understanding of innovation processes in this linear model is that innovations start with the basic research (scientific breakthroughs), that it gradually propagates to a more detailed and more elaborate body of knowledge in the form of applied research and, finally, that it becomes commercial and technological useful knowledge in the form of development research and commercialization.[3] The assumption that there is a one-way stream of learning from the basic to applied research, from applied research to development research and from that to innovation and economic growth is, heuristically, labelled the "linear model" of innovation or the "science-push model". The intervention logic of this policy paradigm was to build a sufficient level of robust research capabilities at national and regional levels that will produce scientific knowledge which – through a chain of knowledge propagation mechanisms – will eventually bring about technological change and economic growth.

National and regional innovation system policies

Gradually, and especially during the 1990s, linear model policies were superseded by a new generation of policy thinking that emphasized the complex and systemic nature of the innovation process. The interplay and collaboration between various types of knowledge actors (Lundvall, 1992; Edquist, 1997) was a central question and concern. In this new line of thought, innovation is the result of collaborations, networks and interactive learning across diverse types of actors, each controlling different, unique and often complementary sets of knowledge, capabilities and resources. Unless this diversity of capabilities and resources are not successfully organized, innovation will never happen. Furthermore, the spatial embeddedness and the broader social and economic context, such as markets, competitors, institutions, infrastructures and policy frameworks, also shape the direction and impact of innovations. Hence, there is more to explain as to how innovations occur than the knowledge-push factors underlying these processes. Firms, universities and other knowledge institutions are of course still key constituents of the innovation processes, but they need inputs to connect to and learn from users, customers, collaborators, competitors and regulators. Thus, the architecture, the creation of linkages and the governance of the "*innovation system*" becomes a central policy priority in all advanced knowledge-based economies. This "systemic approach" implied that universities must, in addition to their traditional roles as educational and research organizations, open up and systematically collaborate with other key actors of the innovation system, in particular the regional and national industry, the public sector and the government.

[3] The first edition of the OECD's comprehensive standard for measuring R&D activities, the Frascati Manual, was published in 1963. Among many fundamental conceptual clarifications, the Frascati Manual also classifies all R&D activities into three generic categories, i.e., "basic", "applied" and "developmental" research.

This dynamic interplay between these three sectors has been coined by Etzkowitz and Leydesdorff (1998) and Etzkowitz and Leydesdorff (2000) as the *Triple Helix*, a metaphor alluding to the concept of the double helix of DNA. The authors argue that because the double helix of the DNA has a specific structure, and because this structure determines the genotypes of its living entity, the structure, quality and strength of interactions between academia, industry and the government determine the rate and probability of success of innovation activities in a given national innovation system.

In the EU, the key policy discussion in the late 90s revolved around the issue of the "European paradox". This discussion referred to the question of why European science produces top-level scientific output and yet fails to transform its knowledge to gain a competitive advantage and to wealth-generating innovations. In particular, European policymakers worried that the main cause of the "*European paradox*" was that European universities lacked the entrepreneurial dynamism exhibited by the American universities, for example, MIT. Dosi et al. (2006) objected that Europe's weaknesses reside in both its system of scientific research and in a relatively weak innovation capacity of its industry (Dosi, Llerena et al., 2006). Either way, the policy implications of this debate was the urgent need to reconsider the quality of European research, to reform the European university system and, especially, to strengthen the university-industry R&D interactions and entrepreneurship (see also the discussion on the European paradox in 5.2.3 in this report).

The EU policies designed to address these issues also had a considerable impact on the Norwegian policies in two different ways: 1) directly, i.e., as Norwegian researchers participated in various EU policy schemes and education policy processes, such as the EU's R&D Framework Programmes, the Bologna Process, etc. (Langfeldt et al., 2012); and 2) indirectly, by adopting these policies within the country, adjusting national laws and developing new national policy schemes that themselves were, into a large extent, a response to impulses from these international and EU policy developments.

The socio-economic paradigms and system transition policies

With the advent of the 21st century, global challenges such as climate change, the need to pursue sustainable economic growth paths, digitalization, population ageing, etc. have served as a motivation for new types of innovative policy thinking. In this context, the policy problem is how to change the evolutionary paths of entire techno-economic trajectories (Perez, 2002), that is, the set of interrelated technologies, organizational and business models and markets by reducing the destructive nature and social costs associated with these path transitions (Stiglitz & Greenwald, 2014).

This new line of policy thinking is therefore not only concerned with the good governance of the national and regional "systems of innovation", but also addresses questions as to how transitions between various "socio-technical systems" occur or should occur, for example, the ongoing transition from carbon-based to carbon-free technological trajectories.

The turn to such large-scale socio-technical transitions calls for a better understanding of the broader societal interactions beyond the R&D and innovation policy domain. Moreover, whereas science and technology-based (STI) innovation policies prioritize R&D support and innovation system policies emphasis on networks, clusters, industry-university collaborations, etc., the new mission-oriented and socio-technical transitions policies acknowledge the importance of other types of social and civic actors in innovation (Nelson, 2011; Schot & Steinmueller, 2016, 2018; Fagerberg, 2017; Mazzucato, 2017).

These insights transcend the techno-economic rationale of traditional industrial policies, and highlight the need for a better understanding of how the sustainability agenda implies altered mentalities, values and lifestyles. System change implies the reconfiguration of entire socio-technical structures of production and consumption. This refers to the need for prioritizing certain policy goals over others, which implies power struggles and conflicting interests between the actors of existing and new socio-technical regimes (Smith et al., 2005; Shove & Walker, 2007; Meadowcroft, 2011).

The types of *failures* justifying the transformational mission-oriented policy paradigm are not any more market (linear model paradigm) or system (innovation system paradigm) failures. In this third innovation policy paradigm, there is a case for system directionality failures, demand articulation failures and policy coordination failures (Weber & Rohracher, 2012).

The important point to make here is that R&D and innovation policy instruments have evolved though the three policy paradigms from grants funding individual researchers, through bilateral university-industry collaborations of increasing organizational and coordination complexity, to even larger and more complex emerging programmes designed to address systemic shifts and socio-technical transitions (Technopolis, 2019).

2.5 A concise picture of Norwegian innovation policy landscape and universities

The preceding discussion is of course relevant for understanding the trajectories of Norwegian higher educational institutions. The objective of this section is to provide a succinct account of how Norwegian innovation policies understand and shape the role of the universities over the last few years.

In 2017, the OECD conducted an independent assessment of the overall performance of the Norwegian innovation system. The OECD (2017) assessed the performance of the national policy system at the government and agency (i.e. the Research Council of Norway, Innovation Norway and SIVA) levels, as well as the level of R&D and innovation performing organizations. We briefly summarize some of the main findings pertaining to universities:

The key finding of the assessment was that the Norwegian innovation and economic system must tackle what is coined as the "triple transition imperative", i.e., to:
- Move towards a more competitive, effective and efficient innovation system;
- Shift towards a more diversified and robust economy that is less dependent on oil revenues; and
- Achieve these structural transformations while supporting research and innovation that can confront an array of societal challenges.

It is unclear how prepared Norwegian universities are to adjust and to contribute to this triple transition.

At the *level of R&D performing sectors,* the OECD report considers the relatively sizeable public research institute sector, the universities and hospitals, and points to a long-standing national concern over the insufficient excellence of research in Norwegian higher education. These concerns were highlighted in the Long-term Plan for Research and Higher Education 2015-2024 and are renewed in its first revision for the period from 2019-2028. Also, the Productivity Commission report, "At a Turning Point: From a Resource-Based Economy to a Knowledge Economy", which was published in 2016, addressed concerns about Norwegian academic excellence.

More specifically, the OECD points to several indicators which suggest that the performance and impact of the Norwegian public research system is good, but not necessarily outstanding, especially in areas of importance to national competitiveness or those aiming to tackle global and national societal challenges. The OECD assessed that the two main reasons for Norway´s underperformance in scientific excellence are: a) the fragmentation and lack of critical mass in the dominant national universities; and b) the lack of a strategic approach underpinning human resource policies within the universities. The OECD's key recommendation for further developing national scientific excellence is to continue *funding centres of excellence (CoEs)* as an effective external driver of change towards a higher quality in the public research sector.

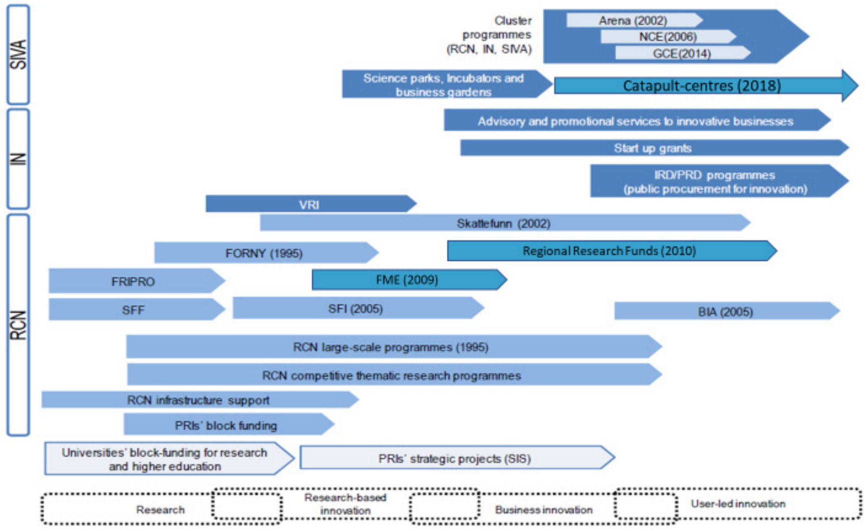
Regarding the *competitiveness of the Norwegian innovation system*, the OECD finds that there is *a good match between the scientific specializations and the pivotal Norwegian industrial clusters*, particularly within petroleum, fisheries and aquaculture, the maritime sector, marine biology and environmental technologies. Klitkou and Kaloudis (2007) are one of several published articles corroborating this finding. Nevertheless, there is still a need to broaden and diversify the national economy. The strong positions established in these sectors are also an important asset for a successful diversification of the economy. The challenge for innovation policies and universities is therefore to create incentives for transition and growth from established sectors in the economy to ones that are new and structurally related to the old sectors.

The OECD 2017 also reviewed the structure of the research and innovation policy scheme landscape in the country. Figure 2 below provides a comprehensive illustration of the most important policy measures.

The most conspicuous feature of the Norwegian R&D and innovation policies over the last two decades is the steadily increasing public funding to support business innovation in Norway. The Research Council of Norway (RCN) funds key innovation policy schemes that require participation from business or public sectors, such as the Skattefunn R&D tax incentive scheme, the User-driven Research-based Innovation Programme (BIA), the Centres of Research-based Innovation (SFI) and the Centres for Environmental-friendly Research (FMEs). Innovation Norway provides seed funding for start-ups and also funds national innovation clusters centres (NCEs and GCEs), and together with the RCN offers a comprehensive portfolio of financial support schemes and technical services to support business innovation.

All these policy measures provide incentives, one way or another, for collaboration between industry and Norwegian academic and research institutions, and hence are important for our analysis. In particular, we focus on the university-industry collaboration and university-industry research centres in Chapter 4.

Figure 2.1: Overview of Norway's main research and innovation support schemes and programmes by funding agency and by relevance to the different types of innovation



The most noteworthy new policy instrument in the Norwegian R&D and innovation policy landscape established after the OECD assessment in 2017 is The *Norwegian Catapult Programme*, a new policy measure designed to assist the establishment and development of catapult centres, with the purpose of accelerating the innovation process in Norwegian business sectors with great economic potential. The programme is managed by The Industrial Development Corporation of Norway (SIVA) in partnership with Innovation Norway and the Research Council of Norway. It is unclear what role universities should play in these catapult centres, and yet there are possible and multiple complementarities between these catapult centres and many of the R&D, innovation and entrepreneurship activities of universities, including the large research infrastructure projects funded by the "National commitment to Research Facilities" programme of the Research Council of Norway. Although these facilities are targeted towards exploration of the research frontiers within their respective fields, there is clearly a scope for a new type of collaboration between these university research infrastructures, catapult centres and industrial research facilities. To the best of our knowledge, there are no strategies as to how to systematically search and exploit such complementarities.

Other important recent changes in the Norwegian policy landscape worth noting in this report are:

- There is an ongoing process aiming at a better alignment and simplification of the policy measures directed to the business sector in Norway, initiated by the Ministry of Trade and Industry. It is very early to estimate what probable effects this process may have on universities' engagement with the policy measures and agencies in question (i.e. RCN, Innovation Norway and SIVA).
- Independently from the realignment of the business innovation policy measures process mentioned above, it has already been decided that local municipalities and

countries will receive more autonomy in implementing regional innovation policy on a greater scale than before, which is a consequence of the restructuring of the county administration level in Norway (i.e. Regionreformen, 2020). Hence, the regional R&D funding scheme (RFFs) is expected to increase in volume, but it is also possible to see more thorough changes in the interface between the regional and national R&D governance levels (Kolltveit, 2017).

- A series of more recent (i.e. published after the OECD's assessment from 2017) evaluations of policy measures such as SFIs, FMEs, the cluster schemes, NCEs and GCEs (commented above), the industry-oriented research institute sector, etc. indicate that it is challenging to evaluate the innovation impact of these schemes in general, and in particular the innovation impact of the participating universities. Here, there is a scope for all participants funded by these schemes, especially NTNU and SINTEF, to explore and develop new methods for documenting pathways and types of innovation impacts from the projects they participate in.

2.6 Policy implications

The discussion above points to some clear, broad societal trends of fundamental importance for universities. Firstly, the nature of economic growth, to a very large extent, is *knowledge-driven and innovation-based*. Furthermore, there are claims in the literature that we are probably witnessing the early phases of the ascendance of knowledge-driven *entrepreneurial economies and societies.* Both observations imply that the role of universities and their three missions, education, research and innovation/entrepreneurship, will be more and more critical in the future for the development of regions and countries, and for achieving the UN's ambitious sustainable developments goals.

Secondly, we identified a strand of literature suggesting that the nature of modern R&D and innovation activities is increasingly more dependent on innovation and entrepreneurial networks, clusters and ecosystems that are becoming more interdisciplinary, and they are spanning across many organizational, institutional and cultural boundaries. Although we did not search the literature discussing digitalization and its effect on R&D and innovation processes per se,[4] there is little doubt that transformative digitalization technologies, which permeate and alter the entire fabric of our societies, also change the way modern R&D and innovation is conducted, from agenda setting, to experimentation, to knowledge-sharing processes and public engagement (Nolan & Guellec, 2019).

It is also unclear how the new mission-oriented transition R&D policies will impact universities in the future. Well-designed policies may provide incentives for individual universities to better direct their own priorities and strategies in the context of an increasing global division of labour.

In other words, the nature of modern research and innovation processes, especially those involving universities, is becoming more *complex* and probably also *more demanding for individual academic research groups* than previously thought. Very much due to the trends and rationales behind the three policy paradigms we presented above, individual researchers and research groups, even the best ones, are facing increasingly more complex policy landscapes in which the funding of R&D is becoming fiercely more competitive and increasingly more dependent on larger inter-disciplinary and cross-institutional networks.

[4] This is a task falling out the scope of this report.

Consequently, one can argue that more than ever individual research groups need support from their departments, faculties and educational institutions, as well as from the policymakers of their regions and countries in order to:

a) Understand developments in a broader policy landscape and being prepared to meet identified challenges as early and as thoroughly as possible;
b) To plan future directions of their own research when connected to the funding opportunities available at the regional, national, EU and global levels; and
c) To facilitate researchers with the creation and maintenance of inter-disciplinary networks in multiple innovation and entrepreneurial ecosystems.

Provided that universities are successful with these courses of action, they should have all the possibilities to combine and leverage in-house knowledge and capabilities stemming from very diverse cognitive areas, which until recently were not considered as pivotal in innovation processes, such as Humanities, Social Sciences and Law, in addition of course to Natural Sciences, Medicine and Engineering. Today, organizing such interdisciplinary combinations are challenging, given the explicit disciplinary model most universities are organized around and funded with. Even so, the imperative of socio-technical shifts represent considerable opportunities for those universities that can understand, engage and shape transformative innovation processes on a global economic and policy formation scale.

Bibliography

Albahari, A. et al. (2017). Technology Parks versus Science Parks: Does the university make the difference? *Technological Forecasting and Social Change* 116: 13-28.

Audretsch, D. B. (2007). The entrepreneurial society. Oxford University Press.

Audretsch, D. B. (2014). From the entrepreneurial university to the university for the entrepreneurial society. *The Journal of Technology Transfer*, 39(3), 313–321.

Autio, E., Kenney, M., Mustar, P., Siegel, D., & Wright, M. (2014). Entrepreneurial innovation: The importance of context. *Research Policy*, 43(7), 1097–1108.

Boschma, R. (2015). Towards an Evolutionary Perspective on Regional Resilience. *Regional Studies* 49(5): 733-751.

Carlsson, B., Jacobsson, S., Holmén, M., & Rickne, A. (2002). Innovation systems: Analytical and methodological issues. *Research Policy*, 31(2), 233–245.

Castellacci, F., & Natera, J. M. (2013). The dynamics of national innovation systems: A panel cointegration analysis of the coevolution between innovative capability and absorptive capacity. *Research Policy*, 42(3), 579–594.

Cohen, W., & Levinthal, D. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly,* 35(1), 128-152. doi:10.2307/2393553.

David, P.A. & Foray, D. (2002). An introduction to the economy of the knowledge society. *International Social Science Journal* 171/2002, 9-23.

Dosi, G. et al. (2006). The relationships between science, technologies and their industrial exploitation: An illustration through the myths and realities of the so-called 'European Paradox." *Research Policy* 35(10): 1450-1464.

Edquist, C. (1997). Systems of innovation: Technologies, institutions and organizations. London, Pinter.

Etzkowitz, H. (1983). Entrepreneurial Scientists and Entrepreneurial Universities in American Academic Science. *Minerva* 21(2-3): 198-233.

Etzkowitz, H., & Leydesdorff, L. (1998). The endless transition: A "triple helix" of university-industry-government relations. *Minerva* 36(3): 203-208.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research Policy*, 29(2), 109–123.

European Commission (2007). Regional Research Intensive Clusters and Science Parks. European Research Area - Regions of Knowledge. European Commission.

Fagerberg, J. (2017). Mission (im)possible? The role of innovation (and innovation policy) in supporting structural change & sustainability transitions. TIK Working Papers on Innovation Studies, TIK Centre, University of Oslo.

Fitjar, R. D., & Gjelsvik. M. (2018). "Why do firms collaborate with local universities?" *Regional Studies* 52(11): 1525-1536.

Fjærli, E., Iancu. D-C., & Raknerud, A. (2018). Effekten av Sivas virkemidler på vekst og verdiskaping. SSB-reports 2018/17.

Gobble, M. M. (2014). Charting the Innovation Ecosystem. *Research-Technology Management* 57(4): 55-59.

Guerrero, M. et al. (2016). Entrepreneurial universities: Emerging models in the new social and economic landscape. *Small Business Economics* 47(3): 551-563.

Haskel J., & Westlake, S. (2018). Capitalism without Capital: The Rise of the Intangible Economy. Princeton University Press.

Hobbs, K. G., Link, A. N., & Scott, J. T. (2017a). Science and technology parks: An annotated and analytical literature review. *Journal of Technology Transfer* 42(4): 957-976.

Hobbs, K. G., Link, A. N., & Scott, J. T. (2017b). The growth of US science and technology parks: Does proximity to a university matter? *The Annals of Regional Science*, 59:495–511.

Isenberg, D. J. (2010). How to Start an Entrepreneurial Revolution. *Harvard Business Review* 88(6): 41-50.

Jakobsen, E. W., Høiseth-Gilje, K., Aagesen, E., Grünfeld, L. A., & Ulstein, H. (2015). Evaluering av eiendomsvirksomheten til Siva. Rapport MENON Business Economics.

Klitkou, A., & Kaloudis A. (2007). Scientific versus economic specialisation of business R&D - the case of Norway. *Research Evaluation* 16(4): 283-298.

Kolltveit, A. (2017). Decentralisation as substantial and institutional policy change: Scrutinising the regionalisation of science policy in Norway. *Science and Public Policy* 44(4), pp. 546-555.

Langfeldt, L., Godø, H., Gornitzka, Å., & Kaloudis, A. (2012). Integration modes in EU research: Centrifugality versus coordination of national research policies. *Science and Public Policy* 39(1): 88-98

Laursen, K., Reichstein, T., & Salter, A. (2011). Exploring the Effect of Geographical Proximity and University Quality on University-Industry Collaboration in the United Kingdom. *Regional Studies* 45(4): 507-523.

Lundvall, B. A. (1992). National Systems of Innovation: Towards a theory of innovation and interactive learning. London, Pinter.

Maasen, P. & Olsen, J.P. (eds.) (2007). University Dynamics and European Integration. Springer.

Mazzucato, M. (2017). Mission-Oriented Innovation Policy - Challenges and opportunities, UCL Institute for Innovation and Public Purpose.

Meadowcroft, J. (2011). Engaging with the politics of sustainability transitions. *Environmental Innovation and Societal Transitions* 1(1): 70-75.
Miller, K., McAdam, M., & McAdam, R. (2014). The changing university business model: A stakeholder perspective. *R&D Management*, 44(3), 265–287.
Minguillo, D., & Thelwall, M. (2015). Research excellence and university-industry collaboration in UK science parks. *Research Evaluation* 24(2): 181-196.
Nelson, R. R. (2011). The Moon and the Ghetto revisited. *Science and Public Policy* 38(9): 681-690.
Nolan, A., & Guellec, D. (2019). The digitalisation of science, technology and innovation. An overview of key developments and policies. OECD, DSTI/STP(2019)14.
OECD (1999). Boosting Innovation: The Cluster Approach, OECD Publishing, www.oecd.org/document/23/0,3343,en_2649_34273_1894871_1_1_1_1,00.htmland http://dx.doi.org/10.1787/9789264174399-en
OECD (2001). Science, Technology and Industry Scoreboard 2001: Towards a Knowledge-based Economy, OECD Publishing, Paris, https://doi.org/10.1787/sti_scoreboard-2001-en.
OECD (2007). Competitive Regional Clusters: National Policy Approaches, OECD Publishing, www.oecd.org/document/2/0,3343,en_2649_33735_38174082_1_1_1_1,00.htm
OECD (2009). Clusters, Innovation and Entrepreneurship, OECD Publishing, www.oecd.org/document/54/0,3343,en_2649_33956792_43874678_1_1_1_1,00.html and http://dx.doi.org/10.1787/9789264044326-en
OECD (2017). OECD Reviews of Innovation Policy: NORWAY- 2017. OECD.
Perez, C. (2002). Technological Revolutions and Financial Capital. Cheltenham, UK/Northampton, MA, USA: Edward Elgar
Porter, M. E. (1998). Clusters and the new economics of competition. *Harvard Business Review* 76(6): 77-90.
Radosevic, S. (2017). EU Smart Specialization in a comparative perspective, In Radosevic et al. (2017) (Eds.), Advances in the Theory and Practice of Smart Specialization, Elsevier Science Publishers, London.
Rossi, F. (2018). "The drivers of efficient knowledge transfer performance: Evidence from British universities." Cambridge Journal of Economics 42(3): 729-755.
Samfunnsøkonomisk analyse AS (2017). Evaluation of Norwegian Innovation Clusters. Report 76-2017. In collaboration with Technopolis group.
Schot, J., & Steinmueller, E. (2016). Framing Innovation Policy for Transformative Change: Innovation Policy 3.0, SPRU Science Policy Research Unit, University of Sussex.
Schot, J.; Steinmueller, W. E. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy* 47(9): 1554-1567.
Shove, E., & Walker, G. (2007). CAUTION! Transitions ahead: Politics, practice, and sustainable transition management. *Environment and Planning A* 39(4): 763-770.
Siegel, D. S., Westhead, P., & Wright, M. (2003). Science parks and the performance of new technology-based firms: A review of recent UK evidence and an agenda for future research. *Small Business Economy* 20 (2), 177–184.
Smith, A. et al. (2005). The governance of sustainable socio-technical transitions. *Research Policy* 34(10): 1491-1510.

Smith, K. (2002). What is the Knowledge economy? Knowledge Intensity and Distributed Knowledge Bases. INTECH Discussion Paper Series. The United Nations University.

Stiglitz, J. E., & Greenwald, B. C. (2014). Creating a Learning Society: A New Approach to Growth, Development, and Social Progress. Columbia University Press.

Technopolis-group (2019). Raising the Ambition Level in Norwegian Innovation Policy: Final report. May 2019. In collaboration with Samfunnsøkonomisk analyse AS.

Valkokari, K. (2015). "Business, Innovation, and Knowledge Ecosystems: How They Differ and How to Survive and Thrive within Them." Technology Innovation Management Review: 17-24.

Weber, K. M., & Rohracher, H. (2012). Legitimizing research, technology and innovation policies for transformative change - combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. *Research Policy* 41: 1037-1047.

Zahra, S., & Wright, M. (2011). Entrepreneurship's next act. *Academy of Management Perspectives*, 25, 67–83.

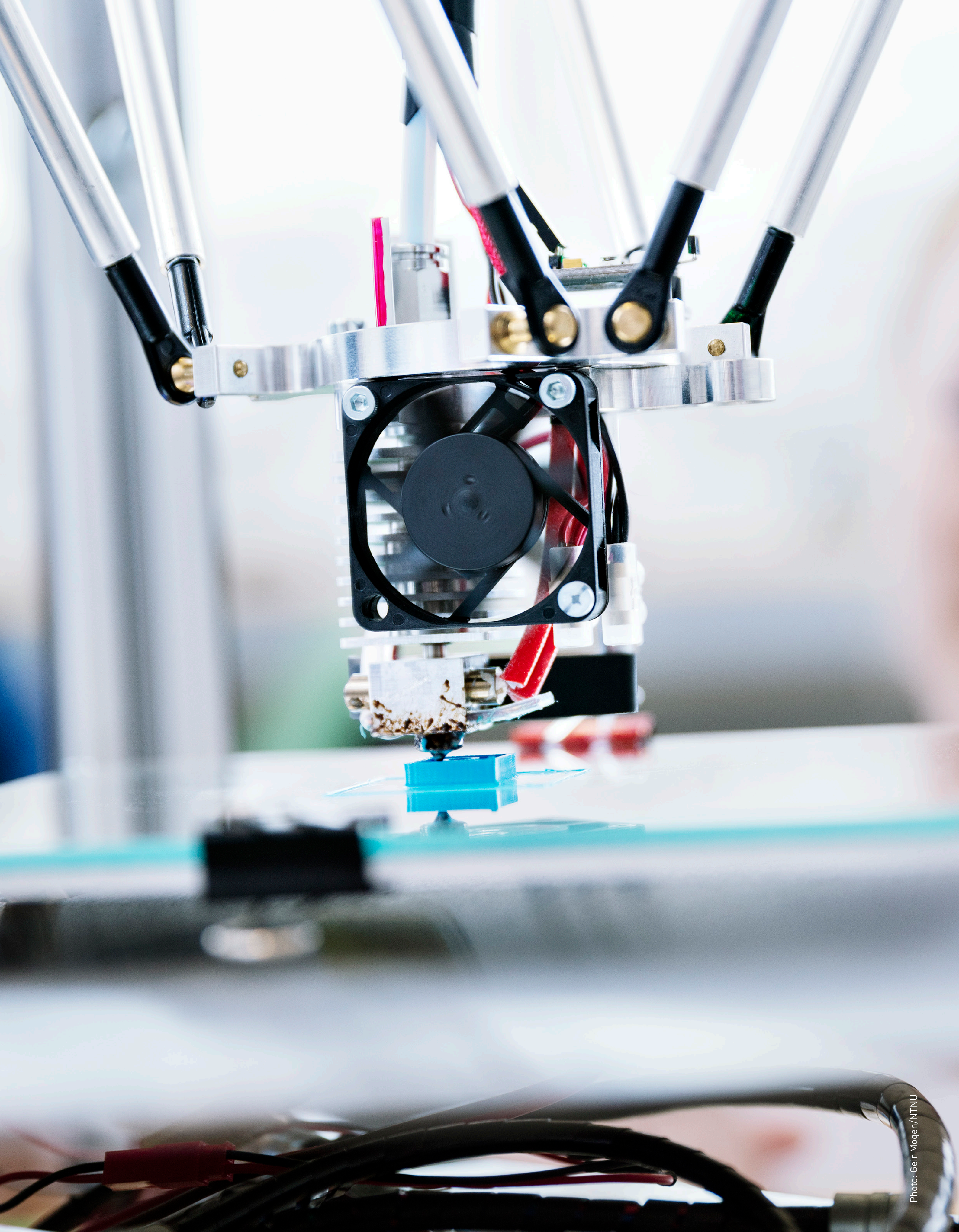


Photo: Geir Mogen/NTNU

3. University-industry channels – an overview

In this chapter, we provide an overview of the main interaction channels between universities and the business sector, and we discuss their relative importance to their innovation impacts.

In a knowledge-driven economy, universities play a vital role in creating new knowledge - solely or in collaboration with external actors, of which knowledge is transferred or integrated into society in general, and into the public or private sector in particular. Firms' interaction with universities may grant access to specialized knowledge and the opportunity to conduct high-quality research (Hussler et al., 2010; Laursen & Salter, 2004; Raesfeld et al., 2012), thereby creating new possibilities for innovation development (Mansfield, 1991; Cohen et al., 2002; Dahlander & Gann, 2010).

University-industry interactions are therefore important to many firms' innovation development and a top priority for policymakers (Ankrah & Al-Tabbaa, 2015; Galán-Muros & Plewa, 2016; Estrada et al., 2016). The policy support for university-industry interactions has thus increased in recent decades, fuelled by the goal of increasing the rate of innovation in the economy (Spencer, 2001; Cohen et al., 2002). Scholars have followed this development and recognized a range of factors that lead firms to interact and collaborate with universities and draw knowledge from them (Bruneel et al., 2010) (see e.g. Tether, 2002; Laursen & Salter, 2004; Mueller, 2006).

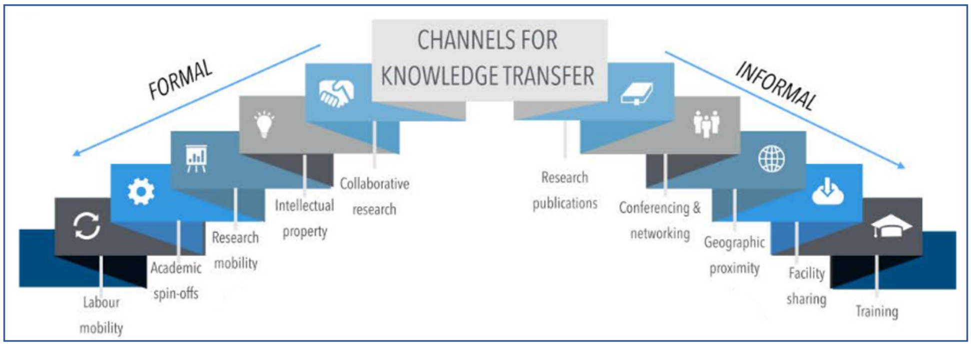
The interactions between universities and firms unfold through various formal and informal channels (Bekkers & Bodas Freitas, 2008; OECD, 2019). This chapter first presents 10 channels for knowledge transfer distinguished by the OECD (2019) that encompasses a broad overview of the channels found to be of importance for university-industry interactions.

3.1 Ten types of channels for university-industry interaction

The 10 channels are divided into five formal- and five informal channels (see Figure 3.1). Formal channels include collaborative research, intellectual property transactions, research mobility, academic spin-offs and university graduates joining industry.

Informal channels include research publications, conferences and networking, facility sharing and the continuing education of company employees (OECD, 2019). In the following, each channel is presented, starting with the five formal channels:

Figure 3.1: Channels for knowledge transfer (OECD, 2019, p. 31)



Collaborative research refers to research projects carried out by university researchers. These projects can be partially or fully funded by industry, and range from small- to large-scale projects. Small-scale projects often happen through contract services and academic consultancy, in which firms commission universities to perform research, while long-term strategic partnerships often consist of multiple actors as stakeholder, such as in university-industry research centres (see Chapter 4.4 for more details on research centres). Research services are often established to solve a concrete firm challenge or to create new knowledge in line with the specifications of the firm, and are generally more applied than research taking place in, for instance, research centres (OECD, 2019; Perkmann & Walsh, 2007).

Intellectual property (IP) transactions refer to the licensing and selling of IP, such as patents and licenses generated by universities to the industry.

Research mobility includes both permanent and temporary assignments of university researchers working in the industry and the converse, such as the Professor II position in Norway. In general, research mobility is deemed to be of importance, because these individuals will act as what is often termed as "knowledge brokers" or "boundary spanners" between universities and industry actors, as these individuals are knowledgeable about both the university and industry sectors (Rosli et al., 2018; Haas, 2015). As such, these individuals can therefore be important channels, or links, which could create better relations and interactions between university and industry partners.

Academic spin-offs are when university researchers (or graduates) develop and commercially exploit knowledge and/or technologies through a company they own, which are often the outcomes of research conducted by these academics.

Labour mobility refers to university graduates who join industry. This channel is often deemed to have one of the biggest impacts on the industry, particularly in some disciplines and industry sectors, based on the share numbers of students who graduate every year. Accordingly, Balconi and Laboranti (2006) argue that students are the most important form of knowledge transfer in the electrical industry.

Informal channels of university-industry interaction that diffuse knowledge from universities to industry, and conversely, include the following:

Research publications are academic writings presented in academic journals and other specialized media. Science-intensive sectors such as biotechnology and pharmaceuticals have strong complementarities with basic academic research and their firm's R&D tend to be able to utilize research publications (Meyer-Krahmer & Schmoch, 1998; Cohen et al., 2002; Perkmann & Walsh, 2007).

Conferencing and networking concern the interaction between university researchers and industry representatives. These interactions can take place in formal conferences or dissemination events, but also in more informal settings such as meetings with- and having contact with former classmates employed in universities and industry (Perkmann & Walsh, 2007; OECD, 2019). These networks are recognized as important for developing and maintaining university-industry collaborations (Powell et al., 1996; Steinmo & Rasmussen, 2018).

Geographic proximity often facilitates networking and informal interactions between university and industry researchers. These informal encounters may be facilitated by locating science parks near university campuses, by firms' laboratories within university campuses or by using the university facilities for a firm's research (OECD, 2019). Research shows that collaborative research is often conducted locally (D'Este & Iammarino, 2010; Mansfield & Lee, 1996), as well as in more peripheral regions (Johnston & Huggins, 2016), which implies the importance of having research institutions in close geographical proximity to industry. A large database of patent applications for 35 OECD countries and China from 1992-2014 shows that 50% of all industrial inventive activity occurred within 30 kilometres of a university (OECD, 2019), which indicates universities' importance for economic growth of their nearby regions (Mueller, 2006).

Facility sharing refers to university and industry partners who share infrastructure, such as laboratories and equipment. It is often expensive to build up a lab; thus, universities often have labs that could be used for both the training of students and doing research for industry. A Norwegian example is the High EFF Lab, which is an advanced research facility to be hosted by SINTEF and NTNU, and one built with a price tag of approximately 50 million NOK. The centre was built as a means to fulfil the goals of research centre HighEFF, which is to enable a reduction in specific energy use and a reduction in climate gas emissions for Norwegian industry (Claussen, 2019).

Training includes courses and continuing education provided by universities to firms, but also lectures held by industry employees at the university. Training is also linked to labour mobility, and for firms there are also possibilities to engage with students during their education.

These 10 channels for knowledge and innovation development between universities and firms are distinct, but still connected. Accordingly, scholars have emphasized that university-industry interaction takes place through a mix of formal and informal channels (Perkmann & Walsh, 2007; Perkmann et al., 2013; Bekkers & Bodas Freitas, 2008). Consequently, scholars have tried to distinguish and cluster the different channels through various conceptualizations that focus on different aspects. For instance, Howells et al. (1998) focus on the levels at which channels are maintained (e.g. individual, group, department, consortia), with Poyago-Theotoky et al. (2002) focusing on whether channels are based on industrial-pull logics or university-push logics. However, these conceptualizations fail to grasp the *relational aspects* of university-industry interactions, which are found to be one of the most important aspects for successful university-industry interactions (Perkmann & Walsh, 2007; Steinmo, 2015; D'Este et al., 2013). Hence, the conceptualization by Perkmann and Walsh (2007) is presented next, as the authors are able to distinguish, cluster and show the relational involvement inherent in the different channels.

3.1.1 A typology of university-industry channels

Perkmann and Walsh (2007) distinguish and cluster the different channels[5] by distinguishing them by the relational involvement between university and industry partners expected to take place in the channels (see Table 3.1). The authors distinguish between high involvement "relationships", such as collaborative research through research partnerships and research services. Next, medium levels of relational involvement are expected to occur through "Mobility", and thus through the channels of academic entrepreneurship and researcher- and labour mobility. "Transfer" activities such as licencing and IPR are expected to have low levels of relational involvement.

Table 3.1: *A typology of university-industry channels (Perkmann & Walsh, 2007, p. 263)*

Extent of relational involvement		
High: relationships	Medium: mobility	Low: transfer
Research partnerships Research services	Academic entrepreneurship Human resource transfer	Commercialization of IP (e.g. licensing)
Use of scientific publications, conferences and networking (can accompany all forms)		

Perkmann and Walsh (2007) build on Schartinger et al. (2002) in their claim that it is "relationships", such as actual research collaborations, that have the highest level of relational involvement, and are more suited for transferring tacit knowledge between firms and universities since they are likely more based on face-to-face contact. Working in such collaborative partnerships, university and industry partners are expected to work together and produce common outcomes. In contrast, "transfer" through, for instance, licensing and patents, does not necessarily require relationships between university and industry partners (Perkmann & Walsh, 2007). Therefore, licensing and patents come closest to what is commonly referred to in the literature as *knowledge- and technology transfer* (Perkmann & Walsh, 2007).

"Mobility" is classified as having an intermediate relational involvement, because graduates starting to work in the industry are more of an infrastructural role for universities (Perkmann & Walsh, 2007). The mobility of university researchers is classified as a medium form of relational involvement, as some links with previous colleagues are often maintained after a researcher moves from the university to work in an industry for shorter or longer periods of time.

Scientific publications, conferences and networking, which were presented from the OECD (2019) framework, are expected to accompany all forms of university-industry interaction. However, the question is then how important are the different university-industry channels? This is the focus of the next section.

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5 The authors use the term "links", as they argue that "channels" are too vague. In the literature, channels and links are often used interchangeably, but there seems to be a stronger preference for using the term "links" over the last decade.

3.2 The importance of specific university-industry channels

In this section, we present empirical findings regarding firms and university researchers´ perceived importance of different channels. The section continues with an illustration of the importance of individuals and ends with a discussion of whether university-industry interactions are detrimental to academic research or not. First, regarding the perceived importance of university-industry channels, Meyer-Krahmer and Schmoch (1998) surveyed German academics, finding that for firms, *formal collaborations with universities are more important than publications and patents*. Similarly, Monjon and Waelbroeck (2003), employing French CIS survey data, reported that firms had the most benefit from contact with universities through formal collaboration. Moreover, the authors found that a formal collaboration with foreign universities is associated with highly innovative firms, which is similar to the findings of Steinmo and Rasmussen (2016), who found that science-based firms were more inclined to work with the best milieus, regardless of geographical proximity.

Bekkers and Bodas Freitas (2008) surveyed both industrial and university researchers in the Netherlands, and found that publications were deemed as the most important outlet by both groups, followed by personal contacts. Interestingly, the instruments usually stimulated by policymakers and university managements, such as Technology Transfer Office (TTO) activities and university patents, received rather low ratings from both groups of respondents. Further, Bekkers and Bodas Freitas (2008) found that the perceived importance of the studied channels for knowledge transfer are relatively similar between industry and university, but that university researchers generally attribute higher importance to all knowledge transfer channels than industrial researchers do.

De Fuentes and Dutrénit (2012) surveyed firms' R&D and product-development managers and academic researchers in Mexico, showing that all interaction channels benefit firms. Yet, the channels related to joint and contract R&D, IPR and human resource mobility (graduates and academics) were reported to have a higher impact on the long-term benefits for firms. Further, based on a large-scale survey of R&D managers in US manufacturing firms, Cohen et al. (2002) found that the main channels resulting in industry impact from university research are published papers and reports, conferences and meetings, informal information exchange, and consulting. Patents and recently hired graduates are deemed somewhat important, whereas licensing is ranked as the least important channel.

Most of the studies on university-industry channels were concentrated on natural sciences and engineering. There have been relatively few studies focusing on the importance of social scientists' (i.e. economics, political science, sociology, geography, business studies and law) role in university-industry knowledge transfer (Gulbrandsen et al., 2011). The lack of research is due in great part to difficulties in measuring social scientists' contributions than of those in, for instance, natural sciences and engineering (Bastow et al., 2014). Accordingly, social scientists often provide skills that are key for innovation development, but are more challenging to capture (measure), such as creative and critical thinking, communication skills and an in-depth understanding of innovation processes (OECD, 2019). Hence, in social sciences, personal contacts and labour mobility are found to have the greatest relevance (Bekkers & Bodas Freitas, 2008; Schartinger et al., 2002). Collaborative research is also common in the social sciences, though to a greater extent with the public sector (Gulbrandsen et al., 2016). Based on a labour force survey in the UK, the OECD (2019) report shows that graduates in social sciences contribute to innovation in a wide range of service sectors.

The key point from this review is that the importance of the channels varies across science fields and industry sectors (OECD, 2019). Accordingly, Cohen et al. (2002) found that patents and licences appear to only be useful channels for technology transfer in a few industries, particularly in the pharmaceutical industry, which "stands out as an anomaly along many dimensions" (Cohen et al., 2002, p. 21). Even in some high-tech industries, such as communications equipment and aerospace, which reported a substantial public research impact, patents and licences achieved scores that were about average.[6]
From the point of view of universities, D'Este and Patel (2007) conducted a large-scale survey of UK academic researchers, and found that university researchers interact with industry through a variety of channels, frequently engaging in channels such as consultancy and contract research, joint research and training, but less so in patenting or spin-out activities. The individual characteristics of researchers have also been found to have a stronger impact than which department or university they belong to, a finding also confirmed by the studies of Perkmann et al. (2013) and Bekkers and Bodas Freitas (2008).

Studying Norwegian academics, Gulbrandsen et al. (2016) support these findings showing that individual-level aspects and disciplinary affiliation are much more important than the institutional-level characteristics of the researchers affiliated university (e.g. degree of applied versus basic research, and research universities versus regional colleges). As a result, external engagement seems to be a central part of many university researchers' work, regardless of their wider university-level variables. Moreover, regarding the universities' location, an urban location was only positively related to participation in external training activities (Gulbrandsen et al., 2016). The study of Fitjar and Gjelsvik (2018) may explain some of these findings, in which they look into why firms collaborate with local Norwegian universities. They find that firms often begin by searching for partners locally and follow satisfying principles, rather than trying to maximize their knowledge spillovers. Some firms also have a long-term perspective, wanting to contribute in building a good local research group that they can harvest in the future (Fitjar & Gjelsvik, 2018).

Hence, there are clear indications in the literature emphasizing the role of individuals on both the firm and university side. In their review of university-industry research centres, Santoro and Chakrabarti (1999) stated that both university and industry champions are important, and they later confirmed the importance of firm representatives (Santoro & Chakrabarti, 2002). However, few studies have responded by studying the individuals who comprise and create these relationships, which is also indicated in the literature by Perkmann et al. (2013), showing that a lot of important quantitative research has been done, but that there is limited in-depth qualitative research on the actual interactions between university and industry partners

[6] However, the findings above indicating the limited importance of patents and licences is in stark contrast to most studies on university-industry interactions, which have predominantly used patents and licences as a proxy for innovation, and which according to Perkmann and Walsh (2007) is much due to easy data accessibility. Because much of the literature on university-industry interaction has also been conducted in pharmaceuticals and biotechnology in the US, it has been suggested that the literature suffers from serious bias (Broström, 2012; Lundvall, 2007), in that "local tendencies in pharmaceuticals and biotechnology in the USA have been generalized to the relationships between university and industry in general" (Lundvall, 2007, p. 97).

(Perkmann et al., 2013; Steinmo & Rasmussen, 2018; Estrada et al., 2016). The importance of this gap is indicated by Santoro and Chakrabarti (2002), in which only five of 202 firms had more than one firm representative involved in the research centres' activities. This indicates that there are a limited number of firm representatives participating in UICs, and that these firm representatives deserve more attention.

The increasing interactions and collaborations between university and industry have raised concerns as to whether collaboration with industry is harming the autonomy and freedom of academic research, and whether it hampers academic output or not. Even so, prior research has been inconclusive regarding whether UICs harm academic output or not (Perkmann & Walsh, 2009; Banal-Estañol et al., 2015). For instance, Godin and Gingras (2000) found no evidence of industrial influence on the direction of research, although research undertaken in collaborations was applied more. Bonaccorsi et al. (2006) found that collaborations with industry might initially improve the production of academic publications, but beyond a certain level the compliance with the expectations of the industry may be too demanding, and thus lower the number of publications. Researchers in the field of academic engagement have also shown that professors with external funding publish more than colleagues without such funding, while professors with funding from industry publish even more (Gulbrandsen & Smeby, 2005; Perkmann et al., 2013).

3.3 Policy recommendations

This chapter presents a literature review of the various types of university-industry innovation channels, and explores their perceived importance by firms and university researchers. In conclusion, three issues seem particularly important:

First, the importance of the university-industry channels are found to differ across science fields and industry sectors (Cohen et al., 2002; Bekkers & Bodas Freitas, 2008; De Fuentes & Dutrénit, 2012).[7] Hence, these findings indicate that "one size doesn't fit all". Thus, policies should be tailored and respond to the specific needs of industry and university actors (OECD, 2019).

Second, the combination of the role of the geographical proximity and the role of key individuals in developing university-industry collaborations points to the following implications: a) Because most collaborations happen within close geographical proximity, as well as being facilitated by social proximity, this illustrates the importance of having universities located in the vicinity of industrial areas, which are often located outside of the large university towns in Norway. However, the transition towards more research-based innovation processes will most likely take time to play out in more peripheral regions with a strong industrial presence, as firms may be captured within a path-dependent trajectory regarding their innovation processes (for an Norwegian example, see Steinmo et al., 2018). The importance of key individuals (and their knowledge bases and absorptive capacity) in the collaboration process for innovation (Haas, 2015; Santoro & Chakrabarti, 1999) also illustrates the importance of having individuals with a high degree of cognitive proximity and mutual understanding regarding university-industry interaction, both at the universities and within industry.

[7] These authors present complementary overviews; Cohen (2002) present differences between industrial sectors, Bekkers and Bodas Freitas (2008) present differences of perceived importance from the view of academics and firms, and De Fuentes and Dutrénit (2012) present a comprehensive overview of prior research.

Third, the contributions of social sciences and humanities in university-industry interactions have been poorly studied. The few studies that exist indicate a potential for contributing to innovation. This calls for a sharper focus on this area, both for researchers studying these fields, and for policymakers who should facilitate social scientist participation in university-industry interactions.

Finally, to end this chapter and introduce the next chapter, two key trends of university-industry channels reported by the OECD (2019) could be mentioned. First, the key trend is the creation of intermediary organizations, such as university-industry research centres. Second, there is a trend to place a greater emphasis on knowledge co-creation that may take place through university-industry collaboration (OECD, 2019). These two trends are the focus of the next chapter.

Bibliography

Ankrah, S., & Al-Tabbaa, O. (2015). Universities–industry collaboration: A systematic review. *Scandinavian Journal of Management,* 31, 387-408.

Balconi, M., & Laboranti, A. (2006). University-industry interactions in applied research: The case of microelectronics. *Research Policy,* 35, 1616-1630.

Banal-Estañol A., Jofre-Bonet, M., & Lawson, C. (2015). The double-edged sword of industry collaboration: Evidence from engineering academics in the UK. *Research Policy,* 44, 1160-1175.

Bastow, S., Dunleavy, P., Tinkler, J., & Aguilera, N. (2014). The impact of the social sciences: How academics and their research make a difference. Los Angeles: Sage.

Bekkers, R., & Bodas Freitas, I. M. (2008). Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? *Research Policy,* 37, 1837-1853.

Bonaccorsi, A., Daraio, C., & Simar, L. (2006). Advanced indicators of productivity of universities. An application of robust nonparametric methods to Italian data. *Scientometrics,* 66, 389-410.

Broström, A. (2012). Firms' rationales for interaction with research universities and the principles for public co-funding. *The Journal of Technology Transfer,* 37, 313-329.

Bruneel, J., D'Este, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university–industry collaboration. *Research Policy,* 39, 858-868.

Claussen, I. C. (2019). *National Laboratories for an Energy Efficient Industry for improved utilization of available industrial surplus heat and a reformation of the efficiency in various industry processes* [Online]. Available: https://www.sintef.no/projectweb/highefflab/ [Accessed 20.07.2019].

Cohen, WM., Nelson, R. R., & Walsh, J. P. (2002). Links and Impacts: The Influence of Public Research on Industrial R&D. *Management Science,* 48, 1-23.

Dahlander, L., & Gann, D. M. (2010). How open is innovation? *Research Policy,* 39, 699-709.

D'Este, P., Guy, F., & Iammarino, S. (2013). Shaping the formation of university-industry research collaborations: What type of proximity does really matter? *Journal of Economic Geography,* 13, 537-558.

D'Este, P., & Iammarino, S. (2010). The spatial profile of university-business research partnerships. *Papers in Regional Science,* 89, 335-350.

D'Este, P., & Patel, P. (2007). University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry? *Research Policy,* 36, 1295-1313.
De Fuentes, C., & Dutrénit, G. (2012). Best channels of academia–industry interaction for long-term benefit. *Research Policy,* 41, 1666-1682.
Estrada, I., Faems, D., Martin Cruz, N., & Perez Santa, P. (2016). The role of interpartner dissimilarities in Industry-University alliances: Insights from a comparative case study. *Research Policy,* 45, 2008-2022.
Fitjar, R. D., & Gjelsvik, M. (2018). Why do firms collaborate with local universities? *Regional Studies,* 52, 1525-1536.
Galán-Muros, V., & Plewa, C. (2016). What drives and inhibits university-business cooperation in Europe? A comprehensive assessement. *R&D Management,* 46, 369-382.
Godin, B, & Gingras, Y. (2000). Impact of collaborative research on academic science. *Science and Public Policy,* 27, 65-73.
Gulbrandsen, M., Mowery, D., & Feldman, M. (2011). Introduction to the special section: Heterogeneity and university–industry relations. *Research Policy,* 40, 1-5.
Gulbrandsen, M., & Smeby, J.-C. (2005). Industry funding and university professors' research performance. *Research Policy,* 34, 932-950.
Gulbrandsen, M., Thune, T., Reymert, I., & Aamodt, P-O. (2016). Universities and external engagement activities: Particular profiles for particular universities? *Science and Public Policy,* 43, 774-786.
Haas, A. (2015). Crowding at the frontier: Boundary spanners, gatekeepers and knowledge brokers. *Journal of Knowledge Management,* 19, 1029-1047.
Howells, J., Nedeva, M., & Georghiou, L. (1998). *Industry-Academic Links in the UK*, Manchester PREST: University of Manchester.
Hussler, C., Picard, F., & Tang, M. F. (2010). Taking the ivory from the tower to coat the economic world: Regional strategies to make science useful. *Technovation,* 30, 508-518.
Johnston, A., & Huggins, R. (2016). Drivers of University-Industry Links: The Case of Knowledge-Intensive Business Service Firms in Rural Locations. *Regional Studies,* 50, 1330-1345.
Laursen, K., & Salter, A. (2004). Searching high and low: What types of firms use universities as a source of innovation? *Research Policy,* 33, 1201-1215.
Lundvall, B. Å. (2007). National Innovation Systems—Analytical Concept and Development Tool. *Industry and Innovation,* 14, 95-119.

Mansfield, E. (1991). Academic research and industrial innovation. *Research Policy,* 20, 1-12.
Mansfield, E., & Lee, J.-Y. (1996). The modern university: Contributor to industrial innovation and recipient of industrial R&D support. *Research Policy,* 25, 1047-1058.
Meyer-Krahmer, F., & Schmoch, U. (1998). Science-based technologies: University–industry interactions in four fields. *Research Policy,* 27, 835-851.
Mueller, P. (2006). Exploring the knowledge filter: How entrepreneurship and university–industry relationships drive economic growth. *Research Policy,* 35, 1499-1508.
OECD (2019). *University-Industry Collaboration: New Evidence and Policy Options,* Paris, OECD Publishing.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., . . . Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy,* 42, 423-442.

Perkmann, M., & Walsh, K. (2007). University–industry relationships and open innovation: Towards a research agenda. *International Journal of Management Reviews,* 9, 259-280.

Perkmann, M., & Walsh, K. (2009). The two faces of collaboration: Impacts of university-industry relations on public research. *Industrial and Corporate Change,* 18, 1033-1065.

Powell, W. W., Koput, K. W., & Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly,* 41, 116-145.

Poyago-Theooky, J., Beath, J., & Siegel, D. (2002). Universities and Fundamental Research: Reflections on the Growth of University-Industry Partnership. Department of Economics, University of St. Andrews.

Raesfeld, A. V., Geurts, P., Jansen, M., Boshuizen, J., & Luttge, R. (2012). Influence of partner diversity on collaborative public R&D project outcomes: A study of application and commercialization of nanotechnologies in the Netherlands. *Technovation,* 32, 227-233.

Rosli, A., De Silva, M., Rossi, F., & Yip, N. (2018). The long-term impact of engaged scholarship: How do SMEs capitalise on their engagement with academics to explore new opportunities? *International Small Business Journal: Researching Entrepreneurship,* 36, 400-428.

Santoro, M. D., & Chakrabarti, A. K. (1999). Building Industry–University Research Centers: Some Strategic Considerations. *International Journal of Management Reviews,* 1, 225-244.

Santoro, M. D., & Chakrabarti, A. K. (2002). Firm size and technology centrality in industry–university interactions. *Research Policy,* 31, 1163-1180.

Schartinger, D., Rammer, C., Fischer, M. M., & Fröhlich, J. (2002). Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants. *Research Policy,* 31, 303-328.

Spencer, J. W. (2001). How Relevant is University-Based Scientific Research to Private High-Technology Firms? A United States–Japan Comparison. *Academy of Management Journal,* 44, 432-440.

Steinmo, M. (2015). Collaboration for Innovation: A Case Study on How Social Capital Mitigates Collaborative Challenges in University–Industry Research Alliances. *Industry and Innovation*, 1-28.

Steinmo, M., Lauvås, T. A., Eidem, P.-A., Salamonsen, K., & Paulsen, M. (2018). Bedrifters innovasjonstilnærming i perifere regioner. *Søkelys på arbeidslivet,* 35, 221-238.

Steinmo, M., & Rasmussen, E. (2016). How firms collaborate with public research organizations: The evolution of proximity dimensions in successful innovation projects. *Journal of Business Research,* 69, 1250-1259.

Steinmo, M., & Rasmussen, E. (2018). The interplay of cognitive and relational social capital dimensions in university-industry collaboration: Overcoming the experience barrier. *Research Policy*.

Tether, B. S. (2002). Who co-operates for innovation, and why: An empirical analysis. *Research Policy,* 31, 947-967.

4. University-industry collaboration (UIC) for research and innovation - and the role of research centres

This chapter examines the literature on one of the most important university channels for innovation, namely direct university-industry collaborations, and in particular, research centres involving industry co-participation.

4.1 University-industry collaboration

The expectations of universities are changing. Universities have traditionally been expected to teach and conduct research. However, as a consequence of increasing international economic competition in recent decades, numerous policymakers have supported increased interaction between universities and industry, pursuant to which universities should make their research more relevant to industry's needs (Cohen et al., 2002). In relation to this, firms have historically organized their R&D internally (Mowery, 1983), but a shift towards more open innovation has occurred, and firms now increasingly seek to complement their in-house knowledge through interorganizational collaborations in general (Hagedoorn, 2002; Chesbrough, 2003; Sampson, 2007), and university-industry collaborations (UIC)[8] in particular (Caloghirou et al., 2001).[9] Through UIC, universities may contribute relevant expertise and knowledge to a firm's technological resource base, and create new possibilities for innovation through research (Mansfield, 1991; Cohen et al., 2002; Dahlander & Gann, 2010).

Still, conducting research that yields both academic publications and industrial innovations is found to be rather challenging for both university and industry partners (Adler et al., 2009; Bruneel et al., 2010; Galán-Muros & Plewa, 2016), as they often have opposing R&D requirements. Firms generally desire more applied research, while universities generally strive for basic research (Lee, 2000; Nelson, 2004; D'Este & Perkmann, 2011). This divergence is related to the differing incentive structures and opposing logics of academic publication and industrial commercialization (Bjerregaard, 2010; Steinmo, 2015; Galán-Muros & Plewa, 2016).

Although these collaborative challenges are widely acknowledged, prior studies have mainly explored the effects of university-industry links (Perkmann & Walsh, 2007; Wirsich et al., 2016), showing that UIC may lead to successful outcomes such as firm innovations (Mansfield, 1991; Cohen et al., 2002; Robin & Schubert, 2013), patents and licences (Cohen et al., 2002; Gulbrandsen et al., 2011; Perkmann & Walsh, 2007), products (Kaiser & Kuhn, 2012) and academic publications (Gulbrandsen & Smeby, 2005; Banal-Estañol et al., 2015).

[8] UIC is often used as an umbrella term, including all types of "public research organizations", which are predominantly government-funded, such as universities, research institutes and research centres (e.g. Perkmann & Walsh (2007); Estrada et al. (2016).

[9] This development has spurred additional concepts such as the triple helix (Etzkowitz & Leydesdorff, 1997) and Mode 2 (Gibbons et al., 1994), which are more concerned with greater demands for the practical relevance of research and science.

Hence, the outcomes of UIC processes are well known (i.e. there is evidence of innovations, patents and licences), while the collaborative *dynamics10* and *processes* that reveal how these outcomes are developed – including the underlying dynamics that lead to them – have been less explored (Perkmann & Walsh, 2007; Thune & Gulbrandsen, 2014; Boardman & Bozeman, 2015). Due to the lack of studies on the collaborative dynamics of UIC, there is also limited knowledge of how collaborations fail to achieve their collaborative targets and what the critical success factors are (Giuliani & Arza, 2009; Bozeman et al., 2013; Steinmo & Rasmussen, 2016).

Consequently, based on the gaps in the literature and the focus of this report, this chapter focuses on- and reviews the development of UICs, guided by the following research question: *"What empirical evidence is available on the development of formal university-industry collaborations aiming at innovation?"* By focusing on UICs, the emphasis is therefore on the processes that often precede or follow either the transfer of intellectual property (Perkmann & Walsh, 2007) or commercialization (Perkmann et al., 2013).

In the next section we provide a definition of UIC, before presenting different types of UIC; research partnerships and research services, and exploring university and industry partners' motives for establishing such UICs. Next, four drivers and barriers of UIC are described, which include implications for successful UICs. Finally, the peculiarities of university-industry research centres are presented before the chapter ends with policy implications.

4.1.1 Defining university-industry collaboration

Most academic papers do not provide a definition of UIC (Galán-Muros & Plewa, 2016), perhaps because of that term's self-explanatory nature. Furthermore, UIC is often considered as a homogeneous activity, although in practice there are different collaboration types (Perkmann & Walsh, 2007; Gulbrandsen et al., 2011; Ankrah & Al-Tabbaa, 2015), which makes it challenging to create a definition that covers all types of UIC. Ankrah and Al-Tabbaa (2015, p. 387) provide a broad definition, defining UIC as "the interaction between any parts of the higher educational system and industry aiming mainly to encourage knowledge and technology exchange". By focusing on the interaction between university and industry partners and their expected output, the definition covers most collaboration types between university and industry partners.

4.2 Different types of UIC: Research partnerships and research services

The scholarly literature provides several characterizations on UICs (Ankrah & Al-Tabbaa, 2015). Perkmann and Walsh (2007) distinguish between research partnerships and research services based on the degree of finalization of the research undertaken (see Figure 4.1).[11] Finalization refers to whether the research pursues a specific (technical, social or economic) purpose (more applied research), or rather gains new knowledge for the sake of itself (more basic research) (Perkmann & Walsh, 2007):

[10] By dynamics and processes in UIC, this chapter refers to the activities, events, practices and interactions enacted by university and industry partners, and how they affect the development of UICs (Lauvås, 2017).
[11] This figure is the continuation of Table 3.1 in Chapter 3.1.1.

Figure 4.1: Degrees of finalization in industry-funded research (Perkmann & Walsh, 2007, p. 268)

Research partnerships	Research services
Collaborative (or sponsored) research University–industry research centres	Contract research Consulting
low ← finalization	→ high

Research partnerships are designed to generate outputs that are of high academic relevance, which can be used in academic publications, and include collaborative research activities, also known as sponsored research and university–industry research centres. Such research partnerships can range from temporary small-scale projects to large-scale organizations (Perkmann & Walsh, 2007), with up to 50 members, such as in the Norwegian research centres of excellence.

Research services are offered by university researchers for industrial clients, and tend to be less exploitable for academic publications. Contract research and most of academic consulting fall under this category, and involves research or consulting carried out against payment (Perkmann & Walsh, 2007). In research services, there is often less academic freedom than in research partnerships, because research services target specific objectives and deliverables. Although the boundaries between contract research and consulting is blurred, contract research is generally commissioned to explore specific, previously unresearched challenges, while consulting exploit's existing knowledge (Perkmann & Walsh, 2007).

The next subsection explores who establish research partnerships and research services, and what motivates these establishments.

4.2.1 Who establish research partnerships and research services, and what are their motivations?

Perkmann and Walsh (2009) find that university partners often initiate and set the agenda for research partnerships that contain basic research (low degree of finalization), and that these projects grant more publications for the university partners than more applied collaborations. Accordingly, Lee (2000) and D'Este and Perkmann (2011) find that most academics collaborate with industries to further and finance their research and learn from them, rather than to commercialize their knowledge. Hence, university researchers are likely to: (1) choose research topics that are perceived to be of interest by their peers, and (2) that advance the knowledge in their specific area through academic publications; and (3) that this is done to rise up the academic ladder (Nelson, 2004). Thus, it is often university partners who initiate new university-industry research centres.

By contrast, firms most often take initiatives toward *research services* targeted for problem-solving activities, in which they obtain assistance from university researchers (Perkmann & Walsh, 2009). Calderini et al. (2007) find that the university researchers who conduct applied research are found to be more likely to produce industrial applications than researchers who conduct basic research. However, applied research leads to fewer academic publications (Perkmann & Walsh, 2009), and therefore conflicts with the long-term goals of most university researchers (Nelson, 2004; D'Este & Perkmann, 2011; Lee, 2000).

Although these findings apply to firms in general, firms differ based on which industry/sector they operate in. Science-intensive sectors such as biotechnology, pharmaceuticals and chemicals have strong complementarities with basic academic research and their firm R&D, and tend to rely on research partnerships and to some degree on research services (Meyer-Krahmer & Schmoch, 1998; Cohen et al., 2002; Perkmann & Walsh, 2007). On the other hand, sectors that rely less on scientific breakthroughs, such as software development, mechanical engineering or metals, have a stronger preference for research services (ibid).

A point that nuances the differences between research partnerships and research services is the timing of research partnerships and research services in the innovation process, where research services are especially required in the latter stages of the innovation process (Polt et al., 2001). Research partnerships, in for example research centres, often lead to research services that are conducted "outside" the research centre (Lauvås, 2017). A notable implication for firms is that research services have comparatively lower entry costs than research partnerships, and requires lower levels of absorptive capacity (Perkmann & Walsh, 2007). Also, the fixed cost of specialized personnel and equipment makes research services a good starting point for industry (Perkmann & Walsh, 2008). This implies that firms wanting to engage in collaborations with university partners could start with research services, before engaging in research partnerships (Lauvås, 2017). The remainder of the review focuses on research partnerships between university and industry partners, as these are the most complex types of UIC to handle for both university and firm partners (Perkmann & Walsh, 2007; Lauvås, 2017).

4.3 Drivers and barriers of UIC – and implications for how to succeed

Although both sides are dependent on the other party and engage with one another to obtain necessary resources and generate synergies (Carayol, 2003; Santoro & Chakrabarti, 1999; Lind et al., 2013), in UICs the partners face an inherent challenge by relying on resources from other organizations known to have diverse perspectives, interests and objects (Pfeffer & Salancik, 2003; Wry et al., 2013). Hence, there are a range of drivers of UIC, as well as barriers, that make UIC challenging (Ankrah & Al-Tabbaa, 2015). Because the realization of the potential benefits of UIC depends on the partners' ability to overcome the barriers (Bruneel et al., 2010; Plewa et al., 2013b), these drivers and barriers present insights for how to succeed in UICs, although the success factors identified in the literature are of a quite general nature (Thune, 2011; Plewa et al., 2013a). The drivers and barriers affecting the development of UIC are based on the review by Galán-Muros and Plewa (2016), and are categorized as "connections", "organizational culture", "internal characteristics" and "relationships".

4.3.1 Connections between university and firm partners

Three connections between universities and firms have been identified as particularly important drivers and barriers for UIC, insofar as finding an appropriate partner and social- and geographical proximity.

The first step in UIC is to find an appropriate partner, which is challenging (Muscio & Pozzali, 2013). The lack of awareness and lack of connections to potential university and industry partners has therefore been found to inhibit UIC (Galán-Muros & Plewa, 2016). In a large-scale survey of UK academics, D'Este and Patel (2007) find that the variety and frequency of interactions with industry, which is not explained by the rankings of their university departments, but rather by the researchers' personal characteristics. Accordingly, firms on their side are found to identify, assess and choose their university partners at an individual, rather than institutional level (Johnston & Huggins, 2018). These findings are in line with literature on R&D alliances, in which organizational-level collaborations are often found to be based on individual members´ social relationships (Perkmann & Walsh, 2007).

Social proximity is therefore found to be central in UIC, referring to actors' relations at the micro-level, involving trust, friendship and common experiences (Boschma, 2005). Social proximity is generally associated with past collaborations and repeated contact between partners (Balland, 2011; Huber, 2012, Davids & Frenken, 2017), and is particularly central to the success of UIC innovation projects, and for the continuing of new UICs (Mora-Valentin et al., 2004; Belderbos et al., 2015; Steinmo & Rasmussen, 2016). As a result, UICs are based to a large extent on prior established relationships (Barnes et al., 2002; Mora-Valentin et al., 2004), but there is little evidence in the literature on how these relationships are created or maintained (Steinmo & Rasmussen, 2018).

Geographical proximity is also found to be of importance in the connection and establishment of UICs (Mora-Valentin et al., 2004), particularly for small firms (Slavtchev, 2013; Dornbusch & Neuhausler, 2015). In their study of 15 successful innovation projects from the Norwegian BIA programme, Steinmo and Rasmussen (2016) found that engineering-based firms tend to rely on geographical and social proximity to universities, while science-based firms rely more heavily on cognitive proximity in establishing UICs. Fitjar and Rodríguez-Pose (2013) also found that firms who established collaborative links with geographically distant universities and research centres dramatically increased their innovation potential. The implications of these findings is that science-based firms are more likely to find collaborative university partners across geographical distances and generate innovations, while engineering-based firms in more peripheral regions with larger distances to universities would have greater difficulties for engaging in UIC, as it is generally easier to establish UICs with someone in close geographical proximity (Nilsen & Lauvås, 2018).

4.3.2 Differing organizational cultures

The large cultural differences between universities and firms have been identified as barriers for UIC, and refer to different motivations, time horizons and communication modes (Steinmo, 2015; Galán-Muros & Plewa, 2016; Bjerregaard, 2010).

First, universities often have a long-term orientation, whereas firms are more oriented toward short-term, applied research that can lead to solutions to current problems (Spithoven et al., 2011). This scenario can lead to tensions between university and industry partners (Ambos et al., 2008), as firms' short-term perspectives are seen as the biggest disadvantage of UICs by university researchers (Meyer-Krahmer & Schmoch, 1998), while the long-term orientation of universities was viewed as a significant barrier by more than two-thirds of firms in the UK (Bruneel et al., 2010).

Consequently, the second and main barrier found in the UIC literature relates to firms and university partners opposing R&D requirements (Perkmann & Walsh, 2007; Bjerregaard, 2010; Steinmo, 2015), in which firms generally desire applied research[12] for industrial innovations, and universities' research that lead to academic publications (Lee, 2000; Nelson, 2004, D'Este & Perkmann, 2011).

Third, communication is found to be critical for UIC development and success (Plewa et al., 2013a), in which differences in terminology and communication styles are likely to inhibit collaboration (Barnes et al., 2002; Galán-Muros & Plewa, 2016). An ongoing theme is that academic researchers lack training in communicating their findings outside of academia (Mittion et al., 2007; Galán-Muros & Plewa, 2016).

4.3.3 Internal firm characteristics

In particular, the internal characteristics of firms are found to matter and deal with four issues: firms' absorptive capacity/cognitive proximity, their firm representatives, firm size and the difference regarding the openness of research results.

First, Fontana et al. (2006) found that firms with a high absorptive capacity used it to collaborate with universities, while firms with a low absorptive capacity had a low probability on collaboration with universities. When it comes to the similarities in partners' knowledge bases, or cognitive proximity (Boschma, 2005), some similar competencies and capabilities between firms and research partners were found to be important for a successful UIC. However, too much similarity may be harmful because complementary knowledge is required for innovation development (Petruzzelli, 2011). Accordingly, firms with a high absorptive capacity and strong knowledge bases are more likely to diffuse the knowledge produced by the universities (Giuliani & Arza, 2009).

Yet, firms often struggle to integrate the knowledge of research results because of the knowledge boundaries between firms and universities (Steinmo, 2015; Miller et al., 2016; Galán-Muros & Plewa, 2016). Hence, prior research has shown that firms are critically dependent on the skills and activities performed by their firm representative to successfully manage the knowledge stemming from universities (Santoro & Chakrabarti, 2002; Knudsen et al., 2017; Takanashi & Lee, 2018). However, in their study of university-industry research centres, Santoro and Chakrabarti (2002) found that only five of 202 firms had more than one firm representative involved in the research centres' activities, which indicates the importance of engaging knowledgeable firm representative(s). Therefore, the knowledge integration activities performed by the firm representative are found to be important in UIC (Lauvås, 2017), as external knowledge and opportunities often require translation before people inside their organizations can understand them (Cyert & Goodman, 1997).

The size of the firms is also found to matter, in which larger firms are most likely to collaborate with universities (Fontana et al., 2006; Roper & Hewitt-Dundas, 2013). In their study of Swedish university-industry research centres, McKelvey et al. (2015) found that the larger firms focused more on knowledge transfer from the centre back to the firm, whereas the small firms used the research centre to develop knowledge

[12] Although some science-intensive sectors may prefer basic research, such as pharmaceuticals, this general statement, as well as the rest of the literature review, corresponds to the R&D preferences of most (Norwegian) industrial sectors (Perkmann et al., 2011; Cohen et al., 2002; Meyer-Krahmer & Schmoch, 1998).

about customer needs in order to create market opportunities, especially through networking with large firms in the research centre.

Finally, while universities' research results are often freely published, firms' R&D strategies often adhere to secrecy and IP-protection measures (Perkmann et al., 2011). Firms often fear that confidential information will be disclosed in UICs (Hall et al., 2001), particularly when participating in consortia and research centres together with competitors. Thus, firms often participate in UICs with competitors on issues other than their core-technology, researching issues faced by the entire industry, such as regulations and environmental challenges (Jakobsen & Steinmo, 2016; Jakobsen et al., 2019).

4.3.4 Relationships between university and industry partners

There has been extensive research on relationship-related drivers of UIC over the last decade, which has shown the importance of commitment, trust and ongoing long-term relations between partners.

First, scholars have found that *commitment* is important in UIC (e.g. Santoro, 2000; Okamuro & Nishimura, 2017), in which Knockaert et al. (2014) found that a higher involvement in research centres affects the firm's network and competence positively. Okamuro and Nishimura (2017) found that a firm's commitment is important for commercialization in UICs. Jarvenpaa and Valikangas (2016) found that *continued participation over time* is important if firms are to influence and reap the benefits from UICs. Thune and Gulbrandsen (2014), in their study of Norwegian research centres, found that limited firm commitment could lead to a "symbolic collaboration", and high firm exit rates.

Second, *trust* is critical for developing UICs (Barnes et al., 2002; Mora-Valentin et al., 2004), and is especially important for reducing commonly found tensions in UIC (Bruneel et al., 2010). Although university and industry partners could experience a "honeymoon period" in the early stages of the collaboration before their differences surfaces (Estrada et al., 2016), university and industry partners are found to collaborate better over time in successful UICs (Estrada et al., 2016; Lundberg & Andresen, 2012; Steinmo, 2015). Hence, ongoing collaborations may reduce the tensions in UIC over time (Thune, 2011), and because previous collaboration promotes trust in UIC (Bruneel et al., 2010; Lhuillery & Pfister, 2009), building and maintaining trust is an important component for long-term UIC (Bruneel et al., 2010; Galán-Muros & Plewa, 2016). Therefore, scholars have found that former collaboration is one of the key factors for explaining successful UICs (Bishop et al., 2011, Bruneel et al., 2010; Núñez-Sánchez et al., 2012).

4.4 University-industry research centres

University-industry research centres are a type of research partnership between university and industry partners of particular interest because they are the predominant policy initiative used to increase UIC in EU and the US (Ponomariov & Boardman, 2010; Gulbrandsen et al., 2015; Chai & Shih, 2016). Research centres are created to produce both innovations and academic publications, resolving the inherently conflicting goals between university and industry partners that have not been satisfactorily fulfilled by other institutions, such as academic departments, firms and research institutes (Youtie et al., 2006; Ponomariov & Boardman, 2010; Gulbrandsen et al., 2015). Such research centres have also been established in Norway, termed "Centres for Environment-friendly

Energy Research" (FME - Forskningssentre for Miljøvennlig Energi) and "Centres for Research-based Innovation" (SFI - Sentre for forskningsdrevet innovasjon), which are two of the most prestigious schemes in Norway.

Research centres were first created in the US, with the National Science Foundation (NSF) establishing research centres in 1972 (Geisler, 1995; Boardman, 2012). Since that time, many developed countries have followed and created research centres, examples of which include the "Cooperative Research Centres" (CRC) programme in Australia and "VINN Excellence Centre" and "Industry Excellence Centre" in Sweden. In the US, there are different types of research centres. The Engineering Research Centre (ERC) programme and centres aim to establish new knowledge bases for nascent and non-existent industries, whereas the Industry-University Cooperative Research Centre (IUCRC) programme assists mature industries by applying existing knowledge (Santoro & Gopalakrishnan, 2001; Boardman, 2012).

Although the research centres established around the globe are inspired by and have many similarities to the US centres, a wide range of terms has been used for these research centres, such as Cooperative Research Centres (Garrett-Jones et al., 2005; Sinnewe et al., 2016; Villani et al., 2017), Government Research Centres (De Fuentes & Dutrenit, 2016) and University-Industry Research Centres (Cyert & Goodman, 1997; Lin & Bozeman, 2006; McKelvey et al., 2015). Still, what is common to most of these research centres, regardless of the term used, is that they are based in a university context and are semi-independent from the university setting in which they exist.

Research centres seldom have their own research equipment or labs, and often use university facilities for experiments. These researchers perform research with an explicit mission of promoting cross-sector collaboration, knowledge and technology transfer, and ultimately innovation (Boardman & Gray, 2010). Accordingly, research centres are often interdisciplinary in nature, seeking to overcome specific challenges in particular industries (Gulbrandsen et al., 2015; Villani et al., 2017) or to tackle specific societal challenges (Hessels et al., 2014).

The centres are funded in part by industry through membership fees paid by firms that join the centres. In research centres, as it is for UICs in general, there is a difference in firms' motives for participating, in which large firms often participate in UIRCs to advance non-core technologies, while small firms want to advance core technologies (Santoro & Chakrabarti, 2002; McKelvey et al., 2015). This is also evident by studying the firms participating in the Norwegian research centres, where the large industrial firms participate in many research centres, which is not at the core of their business operation competences.

Regarding the continuation of research centres, Feller et al. (2002) found that firm participation in research centres was relatively fragile and likely to be discontinued when the public funds for the initiative ended. A related finding by Perkmann and Walsh (2009) showed that knowledge-building projects containing basic research in engineering-based fields had less interaction between university and industry partners than more applied projects. Whereas the intention has been that the Norwegian research centres (SFI and FME) should also continue their activities after the public funding of the research centres stops, three issues makes the intention less likely to be fulfilled: (1) The literature shows that market failures cause firms to underinvest in research and innovation (Nelson, 1959; Arrow, 1962); hence, the public policy and funding are therefore often put in place to remedy this negative externality (Clarysse et al., 2009; Dimos & Pugh, 2016; Marino et al., 2016); (2) the centres are quite bureaucratic organizations (Thune & Gulbrandsen, 2014; Sinnewe et al., 2016); thus, from a transaction costs perspective, Sinnewe et al. (2016) state that firms could not be expected to pay a greater cost for these highly formalized and hierarchical centres; (3) the industry sectors that participate in the Norwegian research centres are often more inclined towards applied research (see e.g. Meyer-Krahmer & Schmoch, 1998; Cohen et al., 2002); and (4) firms often participate in centres with more basic research profiles in order to build the knowledge bases of researchers, with the intention to harvest these bases later on through more applied research services (Lauvås, 2017).

4.5 Policy implications

This chapter has presented a comprehensive review of UIC, exploring different types of UIC, drivers and barriers, in addition to the peculiarities of UIC in research centres. In conclusion, three areas seem particularly important.

First, the success factors in the UIC literature are found to be quite general (Thune, 2011; Plewa et al., 2013a), which relates to the general gap in the UIC literature, namely that the collaborative dynamics and processes that reveal how successful outcomes are developed are less explored (Perkmann & Walsh, 2007; Thune & Gulbrandsen, 2014; Boardman & Bozeman, 2015). For this reason, it is challenging for firms, universities, scholars and policymakers in UIC to assess and evaluate the success and impact of UICs (Thune, 2011; Perkmann et al., 2011). This is greatly due to the uncertain nature of basic research, which makes it difficult to set clear objectives and evaluate outcomes that may come years after the UIC has ended (Perkmann et al., 2011). Moreover, firms' motives for collaborating with universities are often based on indirect and generic benefits, such as accessing students and academics, acquiring insights into the latest blue-sky research and developing their own, or researcher's knowledge bases (Lauvås, 2017). Firms are therefore found to be less concerned about making a quantitative case for participation (Perkmann & Walsh, 2007; Perkmann et al., 2011; Broström, 2012). Furthermore, there is a relationship between more long-term research partnerships (e.g. research centres) and short-term research services, in which research partnerships, for example in research centres, often lead to research services that are conducted "outside" the realms of the research centre (Lauvås, 2017; Iglebæk et al., 2018).

Second, while most research on UIC has been conducted in science-based industries such as pharmaceuticals and biotechnology (Lundvall, 2007; Broström, 2012), this chapter has pointed towards some nuances regarding the firm's size, characteristics and industrial affiliation, and the importance of different dimensions of proximity. Geographical proximity towards universities is important for the establishment of UICs for both small- and engineering based-firms (Slavtchev, 2013; Dornbusch & Neuhausler, 2015; Steinmo & Rasmussen, 2016). Hence, in an effort to increase UIC, collaborations with local universities can be an important starting point for these types of firms (Steinmo & Rasmussen, 2016; Fitjar & Gjelsvik, 2018), especially as former collaboration is one of the key factors for explaining successful UICs (Bishop et al., 2011; Bruneel et al., 2010; Núñez-Sánchez et al., 2012).

Third, firms´ involvement and commitment in UICs is important in building firms´ absorptive capacity (Santoro & Chakrabarti, 2002; Knudsen et al., 2017; Fontana et al., 2006). This is also indicated in a recent report by the OECD (2019), which recommends focusing on knowledge co-creation between universities and industry, rather than a knowledge-transfer approach. While the SFI evaluation discusses the alternative of having only industrial cash contributions and no in-kind (Damvad, 2018), the literature provided in this chapter points towards having more and not less interaction between university and industry partners to harness the potential of UICs.

Bibliography

Adler, N., Elmquist, M., & Norrgren, F. (2009). The challenge of managing boundary-spanning research activities: Experiences from the Swedish context. *Research Policy,* 38, 1136-1149.

Ambos, T. C., Mäkelä, K., Birkinshaw, J., & D'Este, P. (2008). When Does University Research Get Commercialized? Creating Ambidexterity in Research Institutions. *Journal of Management Studies,* 45, 1424-1447.

Ankrah, S., & Al-Tabbaa, O. (2015). Universities–industry collaboration: A systematic review. *Scandinavian Journal of Management,* 31, 387-408.

Arrow, K. J. (1962). Economic welfare and the allocation of resources for invention. In R. Nelson (Ed.), *The rate and direction of inventive activity.* Princeton, NJ: Princeton University Press.

Balland, P.-A. (2011). Proximity and the Evolution of Collaboration Networks: Evidence from Research and Development Projects within the Global Navigation Satellite System (GNSS) Industry. *Regional Studies,* 46, 741-756.

Banal-Estañol, A., Jofre-Bonet, M., & Lawson, C. (2015). The double-edged sword of industry collaboration: Evidence from engineering academics in the UK. *Research Policy,* 44, 1160-1175.

Barnes, T., Pashby, I., & Gibbons, A. (2002). Effective University – Industry Interaction: A Multi-case Evaluation of Collaborative R&D Projects. *European Management Journal,* 20, 272-285.

Belderos, R., Carree, M., Lokshin, B., & Sastre, J. F. (2015). Inter-temporal patterns of R&D collaboration and innovative performance. *The Journal of Technology Transfer,* 40, 123-137.

Bishop, K., D'Este, P., & Neely, A. (2011). Gaining from interactions with universities: Multiple methods for nurturing absorptive capacity. *Research Policy,* 40, 30-40.

Bjerregaard, T. (2010). Industry and academia in convergence: Micro-institutional dimensions of R&D collaboration. *Technovation,* 30, 100-108.

Boardman, P. C. (2012). Organizational capital in boundary-spanning collaborations: Internal and external approaches to organizational structure and personnel authority. *Journal of Public Administration Research and Theory,* 22, 497-526.

Boardman, P. C., & Bozeman, B. (2015). Academic faculty as intellectual property in university-industry research alliances. *Economics of Innovation and New Technology,* 24, 403-420.

Boardman, P. C., & Gray, D. (2010). The new science and engineering management: Cooperative research centers as government policies, industry strategies, and organizations. *The Journal of Technology Transfer,* 35, 445-459.

Boschma, R. (2005). Proximity and Innovation: A Critical Assessment. *Regional Studies,* 39, 61-74.

Bozeman, B., Fay, D., & Slade, C. (2013). Research collaboration in universities and academic entrepreneurship: The-state-of-the-art. *The Journal of Technology Transfer,* 38, 1-67.

Broström, A. (2012). Firms' rationales for interaction with research universities and the principles for public co-funding. *The Journal of Technology Transfer,* 37, 313-329.
Bruneel, J., D'Este, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university–industry collaboration. *Research Policy,* 39, 858-868.
Calderini, M., Franzoni, C., & Vezzulli, A. (2007). If star scientists do not patent: The effect of productivity, basicness and impact on the decision to patent in the academic world. *Research Policy,* 36, 303-319.
Caloghirou, Y., Tsakanikas, A., & Vonortas, N. S. (2001). University-Industry Cooperation in the Context of the European Framework Programmes. *The Journal of Technology Transfer,* 26, 153-161.
Carayol, N. (2003). Objectives, agreements and matching in science–industry collaborations: Reassembling the pieces of the puzzle. *Research Policy,* 32, 887-908.
Chai, S., & Shih, W. (2016). Bridging science and technology through academic–industry partnerships. *Research Policy,* 45, 148-158.
Chesbrough, H. W. (2003). *Open innovation: The new imperative for creating and profiting from technology*, Harvard Business School Press.
Clarysse, B., Wright, M., & Mustar, P. (2009). Behavioural additionality of R&D subsidies: A learning perspective. *Research Policy,* 38, 1517-1533.
Cohen, W., Nelson, R. R., & Walsh, J. P. (2002). Links and Impacts: The Influence of Public Research on Industrial R&D. *Management Science,* 48, 1-23.
Cyert, R. M., & Goodman, P. S. (1997). Creating effective University-industry alliances: An organizational learning perspective. *Organizational Dynamics,* 25, 45-57.
D'Este, P., & Patel, P. (2007). University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry? *Research Policy,* 36, 1295-1313.
D'Este, P., & Perkmann, M. (2011). Why do academics engage with industry? The entrepreneurial university and individual motivations. *The Journal of Technology Transfer,* 36, 316-339.
Dahlander, L., & Gann, D. M. (2010). How open is innovation? *Research Policy,* 39, 699-709.
DAMVAD (2018). Evaluation of the Scheme for Research-based Innovation (SFI). In Norway, R. C. O. (Ed.).
Davids, M., & Frenken, K. (2017). Proximity, knowledge base and the innovation process: Towards an integrated framework. *Regional Studies*, 1-12.
De Fuentes, C., & Dutrenit, G. (2016). Geographic proximity and university-industry interaction: The case of Mexico. *The Journal of Technology Transfer,* 41, 329-348.
Dimos, C., & Pugh, G. (2016). The effectiveness of R&D subsidies: A meta-regression analysis of the evaluation literature. *Research Policy,* 45, 797-815.
Dornbusch, F., & Neuhausler, P. (2015). Composition of inventor teams and technological progress - the role of collaboration between academia and industry. *Research Policy,* 44, 1360-1375.
Estrada, I., Faems, D., Martin Cruz, N., & Perez Santa, P. (2016). The role of interpartner dissimilarities in Industry-University alliances: Insights from a comparative case study. *Research Policy,* 45, 2008-2022.
Feller, I., Ailes, C. P., & Roessner, J. D. (2002). Impacts of research universities on technological innovation in industry: Evidence from engineering research centers. *Research Policy,* 31, 457-474.
Fitjar, R. D., & Gjelsvik, M. (2018). Why do firms collaborate with local universities? *Regional Studies,* 52, 1525-1536.

Fitjar, R. D., & Rodríguez-Pose, A. (2013). Firm collaboration and modes of innovation in Norway. *Research Policy,* 42, 128-138.

Fontana, R., Geuna, A., & Matt, M. (2006). Factors affecting university-industry R and D projects: The importance of searching, screening and signalling. *Research Policy,* 35, 309-323.

Galán-Muros, V., & Plewa, C. (2016). What drives and inhibits university-business cooperation in Europe? A comprehensive assessement. *R&D Management,* 46, 369-382.

Garrett-Jones, S., Turpin, T., Burns, P., & Diment, K. (2005). Common purpose and divided loyalties: The risks and rewards of cross-sector collaboration for academic and government researchers. *R & D Management,* 35, 535-544.

Geisler, E. (1995). Industry–university technology cooperation: A theory of inter-organizational relationships. *Technology Analysis & Strategic Management,* 7, 217-229.

Giuliani, E., & Arza, V. (2009). What drives the formation of 'valuable' university–industry linkages?: Insights from the wine industry. *Research Policy,* 38, 906-921.

Gulbrandsen, M., Mowery, D., & Feldman, M. (2011). Introduction to the special section: Heterogeneity and university–industry relations. *Research Policy,* 40, 1-5.

Gulbrandsen, M., & Smeby, J.-C. (2005). Industry funding and university professors' research performance. *Research Policy,* 34, 932-950.

Gulbrandsen, M., Thune, T., Borlaug, S. B., & Hanson, J. (2015). Emerging hybrid practices in public–private research centres. *Public Administration,* 93, 363-379.

Hagedoorn, J. (2002). Inter-firm R&D partnerships: An overview of major trends and patterns since 1960. *Research Policy,* 31, 477-492.

Hall, B. H., Link, A. N., & Scott, J. T. (2001). Barriers Inhibiting Industry from Partnering with Universities: Evidence from the Advanced Technology Program. *The Journal of Technology Transfer,* 26, 87-98.

Hessels, L. K., Wardenaar, T., Boon, W. P. C., & Ploeg, M. (2014). The role of knowledge users in public–private research programs: An evaluation challenge. *Research Evaluation,* 23, 103-116.

Huber, F. (2012). On the Role and Interrelationship of Spatial, Social and Cognitive Proximity: Personal Knowledge Relationships of R&D Workers in the Cambridge Information Technology Cluster. *Regional Studies,* 46, 1169-1182.

Iglebæk, F., Nygård, G., Bruvoll, A., & Christian, G. (2018). Effekter av energiforskningen. In Impello (Ed.), Trondheim.

Jakobsen, S., Lauvås, T. A., & Steinmo, M. (2019). Collaborative dynamics in environmental R&D alliances. *Journal of Cleaner Production,* 212, 950-959.

Jakobsen, S., & Steinmo, M. (2016). The role of proximity dimensions in the development of innovations in coopetition: A longitudinal case study. *International Journal of Technology Management,* 71, 100-122.

Jarvenpaa, S. L., & Valikangas, L. (2016). From Governance Void to Interactive Governing Behaviors in New Research Networks. *Academy of Management Discoveries,* 2, 226-246.

Johnston, A., & Huggins, R. (2018). Partner selection and university-industry linkages: Assessing small firms' initial perceptions of the credibility of their partners. *Technovation,* 78, 15-26.

Kaiser, U., & Kuhn, J. M. (2012). Long-run effects of public–private research joint ventures: The case of the Danish Innovation Consortia support scheme. *Research Policy,* 41, 913-927.

Knockaert, M., Spithoven, A., & Clarysse, B. 2014. The impact of technology intermediaries on firm cognitive capacity additionality. *Technological Forecasting and Social Change,* 81, 376-387.

Knudsen, M. P., Tranekjer, T. L., & Bulathsinhala, N. (2017). Advancing large-scale R&D projects towards grand challenges through involvement of organizational knowledge integrators. *Industry and Innovation*, 1-30.

Lauvås, T. A. (2017). *The dynamics of university-industry collaboration: A longitudinal case study of research centers.* nos. 63-2017, Nord University Business School.

Lee, Y. S. (2000). The Sustainability of University-Industry Research Collaboration: An Empirical Assessment. *The Journal of Technology Transfer,* 25, 111-133.

Lhuillery, S., & Pfister, E. (2009). R&D cooperation and failures in innovation projects: Empirical evidence from French CIS data. *Research Policy,* 38, 45-57.

Lin, M.-W., & Bozeman, B. (2006). Researchers' Industry Experience and Productivity in University–Industry Research Centers: A "Scientific and Technical Human Capital" Explanation. *The Journal of Technology Transfer,* 31, 269-290.

Lind, F., Styhre, A., & Aaboen, L. (2013). Exploring university-industry collaboration in research centres. *European Journal of Innovation Management,* 16, 70-91.

Lundberg, H., & Andresen, E. (2012). Cooperation among companies, universities and local government in a Swedish context. *Industrial Marketing Management,* 41, 429-437.

Lundvall, B. Å. (2007). National Innovation Systems—Analytical Concept and Development Tool. *Industry and Innovation,* 14, 95-119.

Mansfield, E. (1991). Academic research and industrial innovation. *Research Policy,* 20, 1-12.

Marino, M., Lhuillery, S., Parrotta, P., & Sala, D. (2016). Additionality or crowding-out? An overall evaluation of public R&D subsidy on private R&D expenditure. *Research Policy,* 45, 1715-1730.

McKelvey, M., Zaring, O., & Ljunberg, D. (2015). Creating innovative opportunities through research collaboration: An evolutionary framework and empirical illustration in engineering. *Technovation,* 39-40, 26-36.

Meyer-Krahmer, F., & Schmoch, U. (1998). Science-based technologies: University–industry interactions in four fields. *Research Policy,* 27, 835-851.

Miller, K., McAdam, R., Moffett, S., Alexander, A., & Puthusserry, P. (2016). Knowledge transfer in university quadruple helix ecosystems: An absorptive capacity perspective. *R&D Management,* 46, 383-399.

Mittion, C., Adair, C. E., McKenzie, E., Patten, S. B., & Perry, B. W. (2007). Knowledge Transfer and Exchange: Review and Synthesis of the Literature. *The Milbank Quarterly,* 85, 729-768.

Mora-Valentin, E. M., Montoro-Sanchez, A., & Guerras-Martin, L. A. (2004). Determining factors in the success of R&D cooperative agreements between firms and research organizations. *Research Policy,* 33, 17-40.

Mowery, D. C. (1983). The relationship between intrafirm and contractual forms of industrial research in American manufacturing, 1900–1940. *Explorations in Economic History,* 20, 351-374.

Muscio, A., & Pozzali, A. (2013). The effects of cognitive distance in university-industry collaborations: Some evidence from Italian universities. *Journal of Technology Transfer,* 38, 486-508.

Nelson, R. R. (1959). The Simple Economics of Basic Scientific Research. *Journal of Political Economy,* 67, 297-306.
Nelson, R. R. (2004). The market economy, and the scientific commons. *Research Policy,* 33, 455-471.
Nilsen, T., & Lauvås, T. A. (2018). The Role of Proximity Dimensions in Facilitating University-Industry Collaboration in Peripheral Regions: Insights from a Comparative Case Study in Northern Norway. *Arctic Review,* 9, 312-331.
Núñez-Sánchez, R., Barge-Gil, A., & Modrego-Rico, A. (2012). Performance of knowledge interactions between public research centres and industrial firms in Spain: A project-level analysis. *The Journal of Technology Transfer,* 37, 330-354.
OECD (2019). *University-Industry Collaboration: New Evidence and Policy Options,* Paris, OECD Publishing.
Okamuro, H., & Nishimura, J. (2017). Whose business is your project? A comparative study of different subsidy policy schemes for collaborative R&D. *Technological Forecasting and Social Change*.
Perkmann, M., Neely, A., & Walsh, K. (2011). How should firms evaluate success in university–industry alliances? A performance measurement system. *R&D Management,* 41, 202-216.
Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., . . . Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy,* 42, 423-442.
Perkmann, M., & Walsh, K. (2007). University–industry relationships and open innovation: Towards a research agenda. *International Journal of Management Reviews,* 9, 259-280.
Perkmann, M., & Walsh, K. (2008). Engaging the scholar: Three types of academic consulting and their impact on universities and industry. *Research Policy,* 37, 1884-1891.
Perkmann, M., & Walsh, K. (2009). The two faces of collaboration: Impacts of university-industry relations on public research. *Industrial and Corporate Change,* 18, 1033-1065.
Petruzzelli, A. M. (2011). The impact of technological relatedness, prior ties, and geographical distance on university–industry collaborations: A joint-patent analysis. *Technovation,* 31, 309-319.
Pfeffer, J., & Salancik, G. R. (2003). *The external control of organizations: A resource dependence perspective*, Stanford University Press.
Plewa, C., Korff, N., Baaken, T., & Macpherson, G. (2013a). University-industry linkage evolution: An empirical investigation of relational success factors. *R&D Management,* 43, 365-380.
Plewa, C., Korff, N., Johnson, C., Macpherson, G., Baaken, T., & Rampersad, G. C. (2013b). The evolution of university–industry linkages—A framework. *Journal of Engineering and Technology Management,* 30, 21-44.
Polt, W., Gassler, H., Schibany, A., Rammer, C., & Schartinger, D. (2001). Benchmarking industry—science relations: The role of framework conditions. *Science and Public Policy,* 28, 247-258.
Ponomariov, B. L., & Boardman, P. C. (2010). Influencing scientists' collaboration and productivity patterns through new institutions: University research centers and scientific and technical human capital. *Research Policy,* 39, 613-624.

Robin, S., & Schubert, T. (2013). Cooperation with public research institutions and success in innovation: Evidence from France and Germany. *Research Policy,* 42, 149-166.

Roper, S., & Hewitt-Dundas, N. (2013). Catalysing open innovation through publicly-funded R&D: A comparison of university and company-based research centres. *International Small Business Journal,* 31, 275-295.

Sampson, R. C. (2007). R&D Alliances and Firm Performance: The Impact of Technological Diversity and Alliance Organization on Innovation. *Academy of Management Journal,* 50, 364-386.

Santoro, M. D. (2000). Success breeds success: The linkage between relationship intensity and tangible outcomes in industry–university collaborative ventures. *The Journal of High Technology Management Research,* 11, 255-273.

Santoro, M. D., & Chakrabarti, A. K. (1999). Building Industry–University Research Centers: Some Strategic Considerations. *International Journal of Management Reviews,* 1, 225-244.

Santoro, M. D., & Chakrabarti, A. K. (2002). Firm size and technology centrality in industry–university interactions. *Research Policy,* 31, 1163-1180.

Santoro, M. D., & Gopalakrishnan, S. (2001). Relationship Dynamics between University Research Centers and Industrial Firms: Their Impact on Technology Transfer Activities. *The Journal of Technology Transfer,* 26, 163-171.

Sinnewe, E., Charles, M. B., & Keast, R. (2016). Australia's Cooperative Research Centre Program: A transaction cost theory perspective. *Research Policy,* 45, 195-204.

Slavtchev, V. (2013). Proximity and the Transfer of Academic Knowledge: Evidence from the Spatial Pattern of Industry Collaborations of East German Professors. *Regional Studies,* 47, 686-702.

Spithoven, A., Clarysse, B., & Knockaert, M. (2011). Building absorptive capacity to organise inbound open innovation in traditional industries. *Technovation,* 31, 10-21.

Steinmo, M. (2015). Collaboration for Innovation: A Case Study on How Social Capital Mitigates Collaborative Challenges in University–Industry Research Alliances. *Industry and Innovation*, 1-28.

Steinmo, M., & Rasmussen, E. (2016). How firms collaborate with public research organizations: The evolution of proximity dimensions in successful innovation projects. *Journal of Business Research,* 69, 1250-1259.

Steinmo, M., & Rasmussen, E. (2018). The interplay of cognitive and relational social capital dimensions in university-industry collaboration: Overcoming the experience barrier. *Research Policy*.

Takanashi, C. & Lee, K.-J. (2018). Boundary spanning leadership, resource mobilisation, and performance of university-industry R&D projects: A study in a Japanese university. *Technology Analysis & Strategic Management*, 1-15.

Thune, T. (2011). Success Factors in Higher Education-Industry Collaboration: A case study of collaboration in the engineering field. *Tertiary Education and Management,* 17, 31-50.

Thune, T., & Gulbrandsen, M. (2014). Dynamics of collaboration in university–industry partnerships: do initial conditions explain development patterns? *The Journal of Technology Transfer,* 39, 977-993.

Villani, E., Rasmussen, E., & Grimaldi, R. (2017). How intermediary organizations facilitate university–industry technology transfer: A proximity approach. *Technological Forecasting and Social Change,* 114, 86-102.

Wirsich, A., Kock, A., Strumann, C., & Schultz, C. (2016). Effects of University–Industry Collaboration on Technological Newness of Firms. *Journal of Product Innovation Management,* 33, 708-725.

Wry, T., Cobb, J. A., & Aldrich, H. E. (2013). More than a Metaphor: Assessing the Historical Legacy of Resource Dependence and its Contemporary Promise as a Theory of Environmental Complexity. *The Academy of Management Annals,* 7, 441-488.

Youtie, J., Libaers, D., & Bozeman, B. (2006). Institutionalization of university research centers: The case of the National Cooperative Program in Infertility Research. *Technovation,* 26, 1055-1063.

5. Academic Entrepreneurship and its impacts

In this chapter we are turning our focus to another university innovation channel, i.e., academic spin-offs. As in previous chapters, here we are also reviewing the extant literature on the topic of academic entrepreneurship, and we highlight the main, robust findings from the research literature. Over the last decades, universities have been increasingly involved in establishing new ventures aiming to commercialize scientific research results, technologies and inventions (Clarysse et al., 2007; Colombo et al., 2010; Lubik & Garnsey, 2016; Mustar et al., 2008).

These academic spin-offs (ASOs) represent a small fraction of all knowledge transfer from universities, but are still considered to be economically powerful ventures with significant wealth creation potential (Shane, 2004a). In particular, ASOs are expected to enhance regional economic development through new knowledge-based employment, the generation of tax revenues and indirect effects through the dissemination of new knowledge improving the absorptive capacity of the region (Criaco et al., 2014; Hindle & Yencken, 2004; Lawton Smith et al., 2008; Vincett, 2010). In addition, scholars argue that ASOs are important firms because they commercialize research results that might have remained undeveloped otherwise (Fontes, 2005; Mathisen & Rasmussen, 2019). Because academic research has a different or, rather a non-commercial agenda compared with research in industry, this could result in the serendipitous discovery of technologies that can save and protect human life, property and the environment. More generally, ASOs often commercialize technologies with radical technical advances typically not suitable for licencing directly to industry (Clausen & Rasmussen, 2013; Shane, 2004a). ASOs also often engage in a rapid internationalization to grow their innovative and unique technology offering (Bjørnåli & Aspelund, 2012). In other words, ASOs are new ventures with the potential of engaging in the type of entrepreneurial activity that challenges existing technologies and markets (Mohr & Garnsey, 2011; Schumpeter, 1934; Walter et al., 2006).
The high expectations to the economic and societal impacts of ASOs are evident. Yet, the academic entrepreneurship literature has predominantly been concerned with explaining *why* some universities create more spin-offs than others (Mathisen & Rasmussen, 2019; O'Shea et al., 2008), i.e., the process from scientific discovery to venture creation. Albeit important to understand, the literature has paid far less attention to the performance and impact of ASOs, i.e., the process from venture creation to outcome. Hence, there is a significant gap in our understanding of ASOs with respect to how these ventures grow to become successful firms and create economic impact (Colombo et al., 2010; Fini et al., 2018; Mathisen & Rasmussen, 2019; Van Looy et al., 2011). It remains clear that ASOs are the type of entrepreneurial firm that must overcome technological, market and organizational uncertainty when engaging in a complex process of transforming scientific knowledge into commercial products and services (Mathisen, 2017; Rasmussen & Mathisen, 2017).

One of the objectives of this chapter is to provide a short introduction to the academic entrepreneurship phenomenon, emphasizing the impact of ASOs in a Norwegian context. First, after defining certain key concepts, a brief historical backdrop of academic entrepreneurship will be provided. Second, important conceptual and practical differences between the creation and impact of ASOs will be discussed. Furthermore, we address the issue of ASOs in a Norwegian context, with an abbreviated analysis of the complete population of ASOs established in Norway in the period from 1999-2011.

5.1 Defining Academic Entrepreneurship

Academic entrepreneurship can broadly be defined as entrepreneurial activity at academic institutions, including patenting, technology licencing and the spinning off new ventures, all with the objective of commercializing research results discovered by academic researchers (Grimaldi et al., 2011; Rothaermel et al., 2007). As a field of research, it is connected to and overlaps with subjects such as technology and knowledge transfer (see Bozeman, 2000; Perkmann et al., 2013), university-industry collaboration (see Agrawal, 2001; Bozeman et al., 2013) and technology commercialization (see Kirchberger & Pohl, 2016; Markman et al., 2008). Academic entrepreneurship has been studied at several levels (Mathisen & Rasmussen, 2019), ranging from the role of the entrepreneurial university in socio-economic development (e.g. Etzkowitz et al., 2000), down to the entrepreneurial behaviour of scientists (e.g. Huyghe & Knockaert, 2015; Stuart & Ding, 2006). In between are policy-level studies focusing on the effects of legislation and policy instruments (e.g. Goldfarb & Henrekson, 2003; Kochenkova et al., 2016), institutional-level studies focusing on intermediary agents, such as science parks, incubators and technology transfer offices (TTOs) (e.g. Mian et al., 2016; Phan et al., 2005; Siegel et al., 2007a), and firm-level studies focusing on the ASOs themselves (e.g. Djokovic & Souitaris, 2008). In sum, academic entrepreneurship is a multidisciplinary field with many objectives and perspectives.

For the purposes of this chapter, the focus will primarily be on the firm-level perspective of ASOs. Although several definitions (as well as terminology and abbreviations) of ASOs have been proposed in the literature, this chapter defines ASOs as "*New ventures established to commercialize scientific research results, technologies, and inventions from universities and public research institutions*" (Clarysse et al., 2005). Licencing to industry is an alternative channel to commercialize research results. Certain technologies and inventions are therefore more likely and/or suitable to be licenced to industry compared to ASOs (Shane, 2001a, b), while the economic impact generated by licences may be more difficult to identify compared to ASOs, as they often occur in a broader industrial context in combination with other activities. Even though the process of how incumbents transform academic invention into commercial products is very different compared to ASOs, the overall characteristics and distribution of outcomes and impacts generated by ASOs is actually quite similar. Although licencing will not be discussed in detail in this chapter, most of the findings and implications are highly relevant for understanding industry licencing as well.

5.2 The Historical Backdrop of Academic Entrepreneurship

As we pointed out in Chapter 2, the role of the university has evolved over time. Universities are now increasingly expected to commercially exploit their scientific and technological advances (Hayter, 2016b; Leitch et al., 2010; Pries & Guild, 2007; Rothaermel et al., 2007). For this reason, the modern university as a social institution is best understood within the context of "Academic Capitalism" (Slaughter & Rhoades, 2004) or "Triple Helix" (Etzkowitz & Leydesdorff, 2000) frameworks, which emphasize its role in knowledge-based economic development (Hayter, 2011). In this section, we will briefly review how the university has gone through several revolutions with respect to its mandate and role in society.

5.2.1 The rise of the entrepreneurial university

The first academic revolution occurred when the *research university* evolved in the late 18th century Germany. The mission of the medieval university was the preservation and transmission of knowledge in the liberal arts, shaped by the dominant influence of the Church. In the wake of the Enlightenment, the university's objective evolved to also include the discovery and advancement of new knowledge. Science became the intellectual basis of the university, and to this day the two reinforcing activities of education and scientific research are considered the key missions of the modern university.

One important fact to acknowledge is that research universities have always been an instigator for entrepreneurial activity, as practical advances generally followed scientific discoveries. However, the context, structure and extent of entrepreneurial involvement have changed dramatically over time, driven by changes in and around the university. The second academic revolution evolved in the late 20th century, led by universities in the US. A unique historical feature of the American university system was the land-grant colleges that emerged in the late 19th century, with a specific focus on its practical application in agriculture, military and engineering. This focus was in stark contrast to the ivory-tower nature of the European university model at that time. During the 20th century, US universities were further shaped by massive funding to assist in US war efforts. This resulted in a significant collaboration and interaction among industry, universities and government to solve the demands of the Allied military. In addition to creating many new technologies, this established a long-lasting culture of practical and defense-related research at certain US universities. Towards the end of the 20th century we see the rise of entrepreneurial university, in which academic entrepreneurship is embraced as the third mission of the university. The changing role of the university is still ongoing at universities around the globe, and over the course of the last 30-40 years several key developments have materialized.

5.2.2 Institutionalization and the growth of academic entrepreneurship

Over the last few decades, there has been an increasing institutionalization of academic entrepreneurship activities, thereby facilitating the direct involvement of the university in commercial activities. This process started in the 1980s, when the US enacted new legislation and policies that aimed to formalize and encourage the commercial utilization of scientific discoveries at universities. Many European countries have since followed with similar initiatives. The most important of these changes were policy changes, which transferred the control and ownership of inventions to the university. In the US, legislation was enacted that centrally transferred the control of discoveries from the federal government to the university. In Europe the situation was different, where many countries operated with a system in which university scientists owned the rights to their own discoveries. This system is usually referred to as the *Professor Privilege* (Fini et al., 2017). Many European countries, including Norway, have enacted new legislation which transferred the control of intellectual property from the scientists to the universities. What these legislations have in common is that they established formalized rules regarding IP ownership, in addition to a greater incentive for universities to exploit commercial opportunities based on research discoveries.
As a consequence of this, new institutions facilitating academic entrepreneurship started to emerge. Although many universities had existing initiatives in place, a large-scale

formalization of technology transfer took place in both the US and Europe. Perhaps the most important institutions invented were the technology transfer office (TTOs) and similar boundary-spanning agents at the university (Geuna & Muscio, 2009). TTOs are organizations responsible for managing the technology transfer process. Before the 1980s, there were almost no TTOs anywhere. Stanford University was one of the first to establish its own TTO in the early 1970s. In Europe, the first example was likely at the KU Leuven in the mid-70s. Over the last 30 years, almost all larger research universities have established some form of TTO, also if no legislation has promoted it directly (Link et al., 2007).

A rapid increase in academic entrepreneurship has followed these policy initiatives. However, research strongly suggests that other factors can help explain this growth. Some researchers have called the effects of legislation overemphasized, as academic entrepreneurship was also on the rise prior to these reforms (Chiesa & Piccaluga, 2000; Clarysse et al., 2007; Mowery, 2011; Mustar et al., 2008). One proposed explanation for this is the rise of the biomedical and ICT research fields. These are the major technological areas of formal technology transfer today, and they grew into important fields of research during this time period. There was also the introduction of new patent laws, which provided much stronger protection, e.g., for biomedical discoveries (Shane, 2004b). Another proposed reason is the increase in industry involvement and the sponsoring of university research. This is believed to have generated new interactions and opportunities due to the occurrence of more applied research. Lastly, there is also likely the presence of feedback loops. When more academic entrepreneurship started to take place, this provided legitimacy and enhanced the culture at the university to engage in more commercial activity.

5.2.3 The European Innovation Paradox

The existence of a European "innovation paradox" is based on the notion that Europe has strong higher education systems, research infrastructure and research results, but fails to translate this into marketable innovations at the same pace as the US (Clarysse et al., 2007). Europe is also performing well compared to the US in publications, but is less competitive in patenting, licencing and new firms established at universities (Siegel et al., 2007b). Although there is a substantial variation between European countries in this regard, where the UK and Sweden are often found to lead European countries, transforming European success in basic research into commercial success seems to have been quite difficult.

Many reasons have been proposed for this: One set of reasons relate to the European university being more distant from industry, thus producing research less adapted to practical use (Goldfarb & Henrekson, 2003). A related issue is the relative lack of entrepreneurial spirit of European scientists, and that to a larger degree European universities view academic entrepreneurship as inappropriate (Renault, 2006). The lack of technology hotspots such as Silicon Valley, and less availability of risk capital in Europe compared to the US, are also viewed as important elements to help facilitate prosperous academic entrepreneurship output (Wright et al., 2007). The bottom line is that Europe has implemented a range of policies that attempt to emulate the US successes in the field, but with all things considered, Europe seems to still have a gap compared to the US regarding academic entrepreneurship. Given its relevance and complexity, the promotion of science commercialization is a central feature of government and university policy in most European countries today (Fini et al., 2018).

5.3 Academic Entrepreneurship: The Process from Discovery to Impact

The vast majority of research on ASOs has focused on the antecedents of spin-off activity, more specifically on how individual (e.g. scientist, entrepreneur), institutional (e.g. university, technology transfer office) and environmental (e.g. legislation, ecosystems) conditions impact spin-off creation (O'Shea et al., 2008). This "black box" approach to ASOs implicitly assumes that firms are homogeneous (Mustar et al., 2008), and that the number of firms corresponds to economic impact (Harrison & Leitch, 2010). The former is challenged by researchers finding that ASOs are a surprisingly heterogeneous group of firms that differ in terms of resources, business model and institutional links (Mustar et al., 2008). Scholars have questioned the expected impact of ASOs, arguing that they are predominantly small firms (e.g. Criaco et al., 2014; Salvador, 2011), showing negligible growth on average (e.g. Hayter, 2011; Wright et al., 2006) and occurring in such small numbers that they have too limited of a total economic impact to justify the public support they receive (Borlaug et al., 2009; Harrison & Leitch, 2010). ASOs also face exceptional growth challenges (Mustar et al., 2008), being characterized with high levels of innovation and often exploiting novel, early-stage and general purpose technologies (Knockaert et al., 2011; Shane, 2001a, b). In addition, ASOs often struggle with attracting critical resources (e.g. Patzelt & Shepherd, 2009; Wright et al., 2006) and knowledge (e.g. Ensley & Hmieleski, 2005; Hayter, 2016a; Rasmussen et al., 2015). Yet paradoxically, when successes do occur, they can generate tremendous impact (Rasmussen & Mathisen, 2017) and many extremely valuable firms, including some of the most important global firms (e.g. Google), originated by virtue of academic research.

In a recent review of the literature on the performance and outcomes of ASOs, Mathisen and Rasmussen (2019) argue that ASOs typically have very long development paths, and outcomes also have to be evaluated over sufficiently long periods of time to capture "real" impacts. Furthermore, ASOs outcomes are highly skewed, with most of the impact accounted for by a few highly successful ventures. Mathisen (2017) also finds that economic impact is not necessarily confined to what happens within the ASO firm but can also take place within other organizations as well. For instance, trade sales appear to be a very common successful outcome, and not accounting for this mechanism may significantly underestimate the impact of ASOs. Lastly, Rasmussen et al. (2016) point to that ASOs can also have an indirect economic impact when acting as technology transfer agents, transferring new technology into application in society. Nevertheless, these impacts are hard to identify because they depend on the interaction among ASOs, industry and the economy more generally.

In sum, it seems evident that a multifaceted understanding of the outcomes and economic impacts created by ASOs is needed, as governments and universities are investing heavily to encourage and support their creation, including establishing TTOs, incubators and internal seed funds (Rasmussen et al., 2006). Obviously, the genuine policy objective is to generate successful firms creating wealth for society, and not just establish many firms.

5.4. Academic Entrepreneurship in Norway

A key factor to consider in the Norwegian context for academic entrepreneurship is the legislative changes enacted in the *"Universitets- og høyskoleloven"* and *"Arbeidstaker-oppfinnelsesloven"* in 2003. The objective of these changes was to provide the universities with a greater responsibility of science commercialization, with the ambition of increasing the return of public investments in scientific research. The "Professor's Privilege" for scientific staff was removed, and the universities were given ownership and control over intellectual property rights (IPR) with commercial value developed at the university. Both the transfer of ownership and the practice of distributing financial dividends between academic staff and the university have been the subject of extensive debate (Grünfeld et al., 2018).

Several reports and evaluations of the legislative changes and policy and support infrastructure for academic entrepreneurship in Norway have been performed over the last decade or so (see e.g. Borlaug et al., 2009; Grünfeld et al., 2018; Rasmussen et al., 2013; Rasmussen et al., 2007; Spilling et al., 2015). The overall picture seems to be that processes around academic entrepreneurship have been significantly professionalized and institutionalized, and generally accepted as an important activity at most Norwegian universities. However, a range of improvement areas has been identified in areas such as the organization and governance of activities, the availability of resources, incentive structures, cultural transformation and the measurement of outcomes and impact. We refer to the sources referenced above for detailed analyses and discussion in these areas.

Mathisen (2017) performed a comprehensive analysis of the Norwegian population of ASOs established in the period from 1999-2011. In this analysis, 373 Norwegian ASOs were longitudinally tracked on the firms' development from their origin through the life cycle on growth, outcomes and key events, until reaching a terminal outcome (or right-censored in 2015 if they survived). The database is unique due to its richness and prolonged time-horizon, and was developed by integrating a range of qualitative and quantitative data sources.[13] It will provide a general but detailed overview of the development and ultimate outcome of ASOs in Norway over a considerable and relevant time period. The database also forms the empirical basis in other published research (e.g. Rasmussen & Mathisen, 2017), including cross-country comparisons of academic entrepreneurship (Fini et al., 2017).

Other scholars have performed similar analyses. For instance, Hvide and Jones (2018) conceptualize the ending of the "Professor's Privilege" in Norway as a natural experiment and attempt to identify the causal effects on academic entrepreneurship, including controls for comparative and general groups. As one key result from their study, Hvide and Jones (2018) found a substantial decline (approximately 50%) in ASOs after the legislative change. As will become clear in the sections below, Mathisen (2017) did not find support for these results, instead finding relatively flat

[13] The population of firms was identified through the FORNY programme, administrated by the Research Council of Norway (RCN). FORNY was the key governmental policy mechanism for promoting the infrastructure supporting the commercialization of research. The programme operated with an incentive model, which ensured that the universities were highly incentivized to report all new ASOs. The advantages of the FORNY programme for research purposes are twofold. First, the FORNY portfolio approximates the full population of such firms in Norway in the focal period, given the reporting incentives and the programme's critical financial importance for universities and TTOs. Second, the continuous reporting of ASOs in real time limits survivorship bias typically associated with retrospective entrepreneurship studies. The empirical database was based on archival data, manually coded data and qualitative sources. The backbone of the database was primarily based on integrating several archival data sources from The National Business Registry in Norway. This included complete financial statements for all firms for all observation years. Over 12,000 corporate announcements (mandatory notices from firms on a number of key corporate events) and patent data was added. In addition, several less structured and qualitative data sources were structured. Examples include all annual reports for all years, the ASOs' original business plans and a comprehensive archive of all news articles ever written about the firms. These unstructured sources were coded into structured form, thus synthesizing this qualitative information into a form that allowed for a quantitative analysis. See Mathisen (2017) for more details.

development in the number of ASOs established. These contrasting results are most likely due to differences in research design and sample identification. For example, Hvide and Jones (2018) identify the ASOs by the (anonymous) matching of employment records with ownership data from new firm incorporation records. As a direct and natural consequence of the "Professor Privilege" ending is the new phenomenon of ASOs in commercializing research results *without* direct (or indirect through holding companies and family) ownership of the academic inventor(s). In these cases, the inventors are receiving their share of future returns through means other than equity. It is well established that many academics prefer to maintain their position at the university, and leave the business of entrepreneurship to others (Salvador, 2011). Hvide and Jones (2018) could not identify these firms, and were thus likely observing a somewhat expected decline in scientist-owned firms, though not necessarily firms commercializing research results per se. Commenting on the study is Lita Nelsen, the long-time head of MIT's Technology Licensing Office: "I would guess that something else is in play besides the fraction of royalties that inventors receive" (Mervis, 2016, p. 396). In other words, Nelsen suggests that these results demand consideration of a wide range of possible influences and relationships Nonetheless, combining the results from Hvide and Jones (2018) and Mathisen (2017) indicate with some confidence that there has not been any increase in new ASOs following the legislation change. Still, Grünfeld et al. (2018) point to a clear upswing in the rate of new ASOs after 2013 following a period of increased public funding of academic entrepreneurship activities.

5.4.1. The development, growth and outcomes of ASOs in Norway

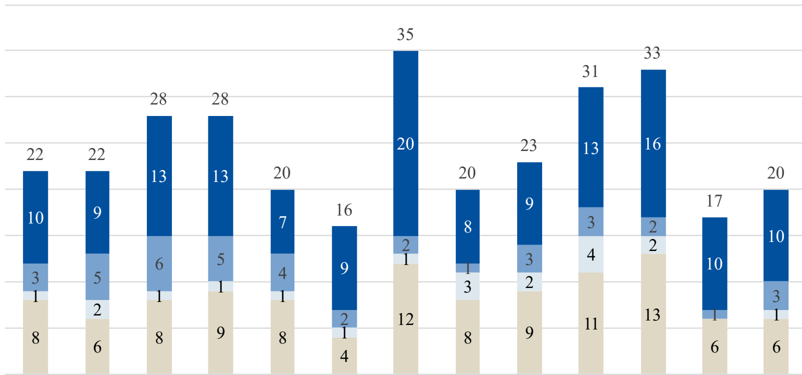
The exposition below provides a brief summary of the development, growth and outcomes of ASOs in Norway from the Mathisen (2017) study. The objective is to provide an overview of the potential economic impacts created by ASOs. Note that events occurring after 2015 are generally not reflected in the results.

Institutional origins

At the start of the observation period (1999), Norway only had four universities, which were prestigious, long-established and research-intensive (hereafter: traditional universities). During a period of reform in the higher education sector in Norway, four former university colleges were approved as new universities in the 2000s (hereafter: new universities). In addition, ASOs can have their origin at university colleges or public research institutions (PRIs).

The four oldest universities are the most important institutions with respect to establishing ASOs, followed closely by PRIs. The academic entrepreneurship literature is predominantly concerned with universities, often overlooking PRIs as a source of ASOs (for notable exceptions see e.g. Clarysse & Moray, 2004; Clarysse et al., 2005; Heirman & Clarysse, 2004; Moray & Clarysse, 2005). This analysis shows that PRIs represent approximately one-third of total establishments. Hence, not taking PRIs into account would miss a significant part of total commercialization activities. PRIs absorb approximately 25% of total public R&D spending in Norway, and are important contributors to national R&D activity. However, this is not unique to Norway, as most European countries have a large number of PRIs (Gulbrandsen, 2011).

Figure 5.1: Absolute number of new ASOs per year (1999-2011) distributed by type of academic parent institution



Together, university colleges and new universities play a quite limited role in commercialization activities. This is somewhat expected due to being significantly less research-intensive institutions. Going deeper, it also becomes evident that a few institutions are dominant within the traditional university category. NTNU represents 46% of ASOs from traditional universities (21% of the total portfolio). A total of 17 PRIs are represented and the concentration of spin-off activity among these is somewhat less pronounced compared with traditional universities. SINTEF is the largest contributor, with 24% of the PRI category, followed by the International Research Institute of Stavanger (IRIS) at 14% and the Institute for Energy Technology (IFE) at 12%. These three institutions represent half of the ASOs established from PRIs. SINTEF is by far the largest PRI in Norway and could thus be expected to establish the largest number of ASOs. SINTEF is also very closely linked to NTNU, and together these two institutions represent 30% of all ASOs in the portfolio. NTNU and SINTEF have a rich history of quite successful commercialization activities, especially within the electronics, information and communication technology (ICT) and maritime technical areas. The analysis confirms that NTNU and SINTEF have a central position in commercializing research in Norway (at least with respect to the number of ventures).

Technology

While industry is a common control variable in management research, it is also a challenging concept in the context of academic entrepreneurship. ASOs are known to commercialize radical and general-purpose technology, which can be exploited in several industries through multiple application areas (Shane, 2001a, b). Consequently, it is arguably more informative to segregate the portfolio based on the type of technologies the ASOs are commercializing. Biomedical and software technologies have generally been found to be the most common technical fields for academic entrepreneurship (e.g. Golob, 2006; Lundqvist, 2014; Shane, 2004a). Figure 5.2 illustrates that this is also the case in Norway, where close to two-thirds of the ASOs are primarily based on biomedicine and/or software:

Figure 5.2: Distribution of ASOs in the portfolio by technological field

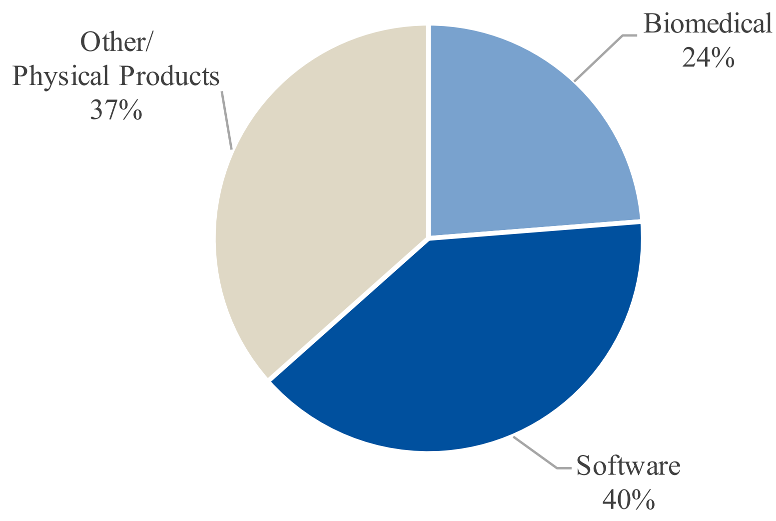
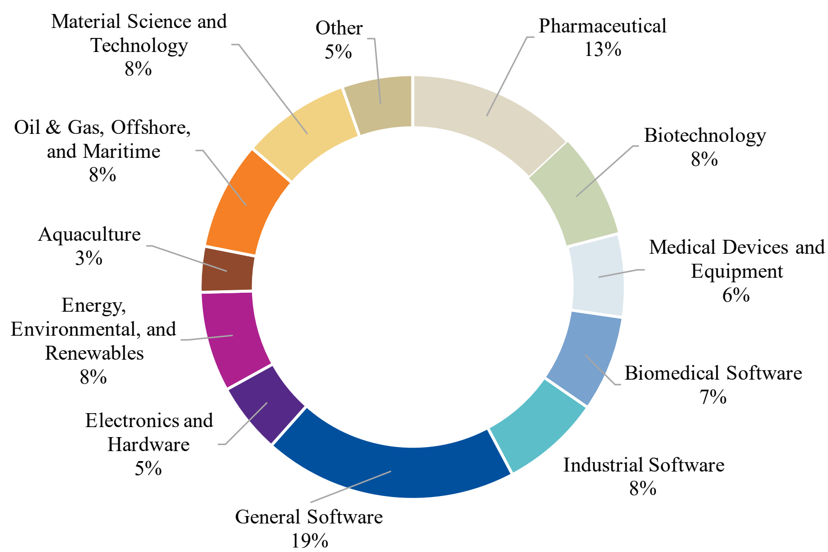


Figure 5.2 is somewhat misleading because, e.g., software technologies can be used for purposes outside what are usually considered as the ICT industry. There is also limited insight into what the Other/Physical Products category contains. Figure 5.3 below provides a classification into technical application areas:

Figure 5.3: Distribution of ASOs in the portfolio by application areas

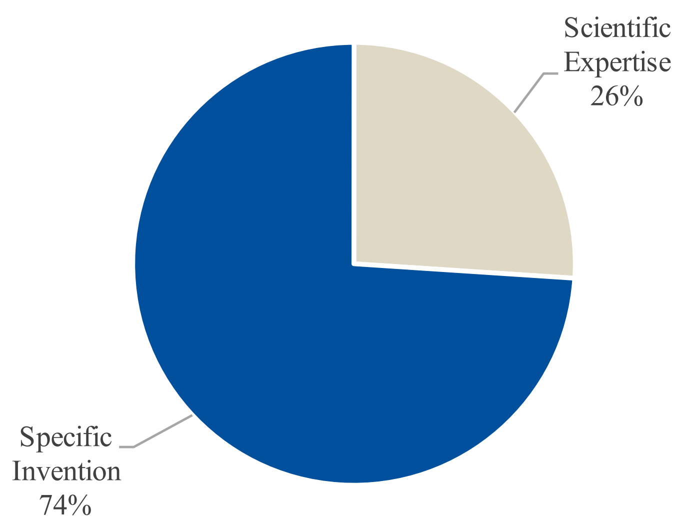


The 11 application areas in Figure 5.3 can roughly be grouped into three technical domains: Life Sciences, ICT and Electronics and Physical Products. This view provides some interesting new details. For instance, the Medical Device and Biomedical Software application areas together represent approximately 13% of the portfolio. While these technologies are not based on the chemical or biological sciences, they still represent a significant proportion of the ASOs, targeting what could be considered the medical industry. Overall, the distribution into technical application areas is in line with previous academic entrepreneurship research (see e.g. Lundqvist, 2014; Shane, 2004a). However, the influence of the industry structure idiosyncratic to Norway is also evident. The Oil & Gas, Offshore and Maritime and Aquaculture application areas are associated with major industries in Norway, with ASOs commercializing physical products and solutions within these application areas representing 11% of all ASOs. Moreover, this is likely an understatement, as ASOs in other categories also target these industries. For example, a substantial amount of ASOs commercializing Industrial Software are targeting the oil and gas and maritime industries.

The ASOs' technological focus is also strongly linked to the research activity of the parent institution. PRIs tend to have a narrow scientific focus, and ASOs created by PRIs overwhelmingly inherit and share the technical domain of their parent. Albeit having a much broader scientific research base, a similar situation exists with universities. The University of Oslo (UiO) represents over 40% of the ASOs in the Pharmaceutical and Medical Device application areas, reflecting their leading scientific position in Norway within the medical area. In contrast, NTNU only represents approximately 10% of ASOs in this area, though being the most important university overall.

The literature has mostly assumed that ASOs are commercializing specific inventions (Karnani, 2013). Even so, ASOs can also be based on non-formalized scientific expertise and tacit knowledge (Pirnay et al., 2003). Figure 5.4 shows that 26% of the ASOs are established based on scientific expertise rather than specific inventions:

Figure 4: Distribution of ASOs in the portfolio based on specific invention vs. scientific expertise



ASOs commercializing specific inventions can opt to legally protect their IP through patents. In certain areas, such as drug development, patenting is extremely common (Thumm, 2004). In other areas, ASOs may favour secrecy and speed over formal

IPR (Hall et al., 2014). For instance, software code can be difficult to patent effectively, and trade secrets are often viewed as a better strategy (Hurmelinna- Laukkanen & Puumalainen, 2007). Overall, 26% of the ASOs commercializing specific inventions applied for a patent(s). However, this figure is pushed downwards by the presence of software firms, in which only 6% have patented inventions. As expected, less than 5% of the ASOs based on scientific expertise have pursued patenting.

Venture Capital - Financing

The academic entrepreneurship literature generally finds that many, if not most ASOs, are reliant on attracting risk capital from venture capitalists (VCs) to finance firm development (Mustar et al., 2006). Figure 5.5 shows the cumulative incidence (for a formal description of cumulative incidence functions please see Scrucca et al., 2007) of VC investments in the portfolio:

Figure 5.5: Cumulative incidence plot estimating the probability of initial VC investment

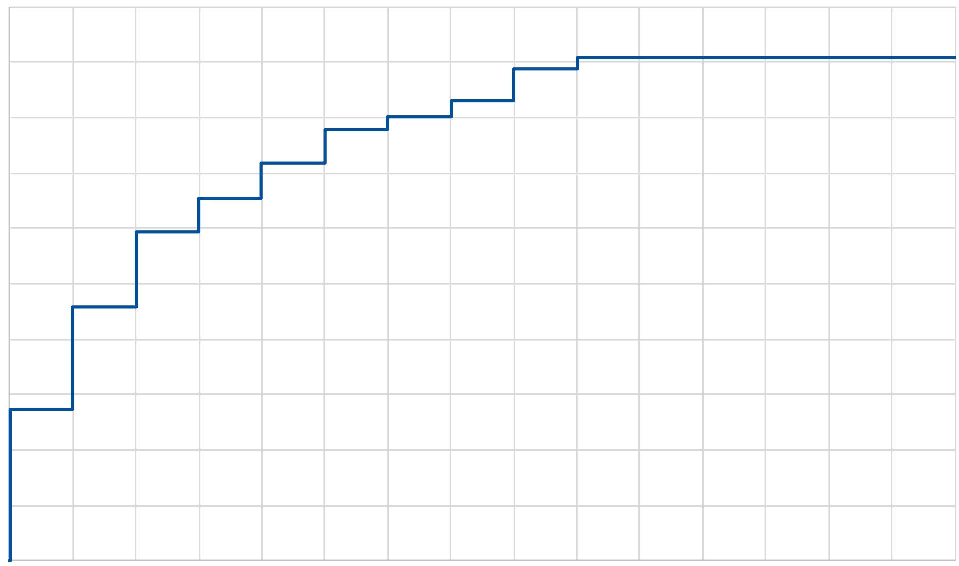


Figure 5.5 essentially estimates the cumulative incidences of initial VC investment in the portfolio, taking into account the timing of occurrences with respect to venture age. Roughly 45% of the ASOs are expected to eventually raise VC funding, and most do so quite early in their development. After four years, one-third of the ASOs had raised some form of VC financing, although no ASO raised initial VC financing after 10 years. When combined, these findings indicate that ASOs are very frequent beneficiaries of VC funding, but that the possibility to raise VC funding declines dramatically after approximately four to six years.

Figure 5.6: Detailed distribution of types of VCs active in the portfolio

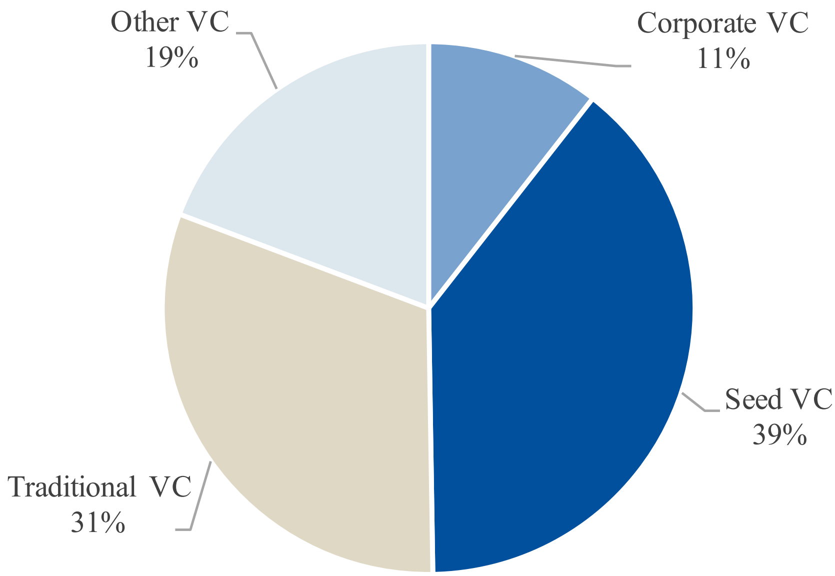
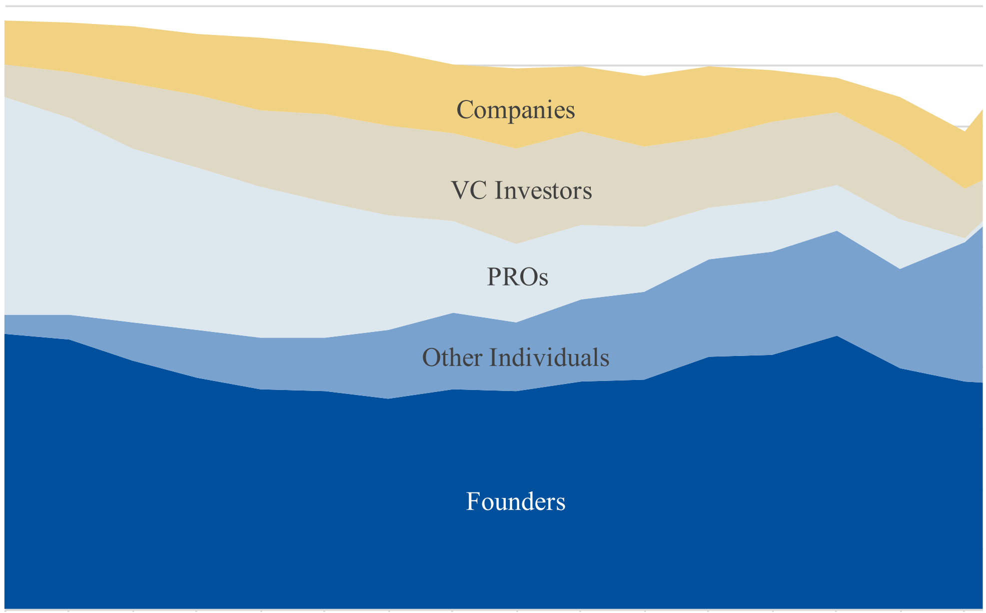


Figure 5.6 shows the distribution of VC investments in more detailed categories. The most common type is VC investors specifically focused on seed investments (i.e. the earliest stage of investment). Most of the seed VCs active in the portfolio manage government-sponsored funds (see e.g. Brander et al., 2014), where the Norwegian government is an investor and/or provides risk adjustments to the private investors. Traditional VCs (mostly private and early-stage funds) represent approximately 31%, whereas corporate VCs fully backed by a corporate incumbent represent 11%. The remaining 19% are a group of VCs that invest in a portfolio structure similar to more traditional VCs, but, in fact, are fully funded by high-net worth individuals or families.

More broadly, professional investors like VCs are not the only external owners in ASOs. Public research organizations (PROs, i.e. both universities and research institutions) are often initial owners in the venture, and other individuals and companies will invest in the firm over time. Figure 5.7 shows the evolution of ownership among four major owner groups.

"Founders" are the largest owner category in the ASOs and on average maintain a 35-45% ownership over time. Together with other individuals (i.e. other private owners such as employees and private investors), individual owners control 45-60% of the ASOs over time. Individuals other than the original founders become relatively more important over time, although the founders still remain the largest group. The distribution of private ownership is rather bi-modal, in which very low (below 5%) and very high (above 95%) ownership is the most frequent. For example, the increase in individual ownership in the oldest firms is primarily due to the relatively higher proportion of ASOs fully owned by individuals at that time.

Figure 5.7: Evolution of ownership structures for ASOs in the portfolio



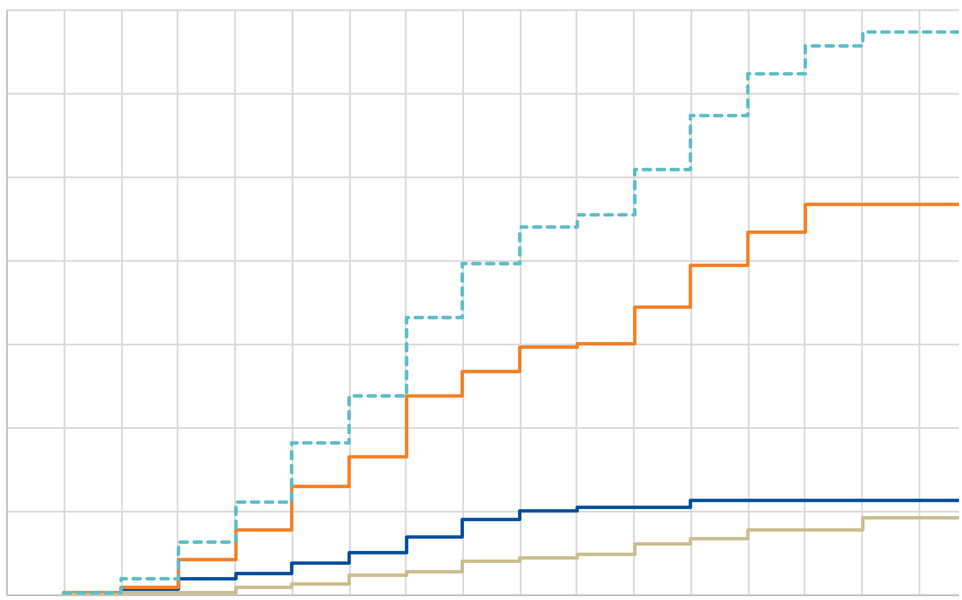
The parent academic institutions (i.e. PROs) are typically quite large owners in the early years, but decrease their ownership significantly over time. This is likely because these stakeholders primarily receive equity as compensation for transferring IPR into the ASO, though typically have a limited ability to invest new capital going forward. In addition, there are notable examples in Norway of TTOs selling shares in ASOs to external investors. More detailed analyses reveal two interesting findings. First, the initial ownership by academic institutions is substantially higher in ASOs established more recently, but the same pattern of decreasing ownership is present. This could be expected as a result of the changes in IPR legislation in 2004. Second, academic ownership has a skewed distribution (and increasingly so over time), illustrated by the median academic ownership being zero as early as in year six. At this point, the clear majority of ASOs do not have any academic owners, and average ownership is affected by a few ASOs with a very high academic ownership (predominantly from PRIs).

VCs and company owners (i.e. public and privately held companies with operational business activities) seem to be of about equal importance. These two groups essentially represent financial and industrial investors, respectively, and together these investors increase ASO ownership over time to roughly 25-30% on average (peaking at around ages seven to nine years). However, VC and company ownership have quite different distributions. Both share a skewed distribution in which zero ownership is clearly the modal condition. However, significant differences arise in the cases when either VC or company owners are present. VC investors typically maintain ownership of approximately 30-50%, and very low/high ownership share is rare. In contrast, moderate company ownership is quite uncommon, with full ownership becoming the modal condition over time. The latter refers to scenarios in which a company has acquired an ASO, but operates the business independently.

Of course, ownership structure will differ significantly based on many factors. This will include circumstances from its origin, but also how resource-demanding and successful the ASO's development process has been. For example, ASOs that do not experience significant growth are typically characterized with a high degree of founder/individual ownership.

Survival and trade sales
Terminal outcomes of ASOs can be categorized as either "failure", "transformed", or "acquired" (i.e. experiencing a trade sale). By definition, ASOs that survive have not achieved either of these outcomes (during the observation period). Figure 5.8 illustrates the evolution of these outcomes, with cumulative incidence curves modeling the three outcomes as competing events (Scrucca et al., 2007).

Figure 5.8: Cumulative incidence plot estimating the probability of competing terminal outcomes.



In sum, one-third of the ASOs are expected to survive (i.e. exist independently) after 15 years. The survival rate appears to be very high, supporting other academic entrepreneurship research (see e.g. Rothaermel & Thursby, 2005; Zhang, 2009). After 10 years, only 30% of ASOs are expected to fail. Contrary to what could be expected, failure by bankruptcy is actually quite rare. Only 23% of failures are due to bankruptcy (or other forced dissolution), thereby implying that most ASO failures are voluntary dissolutions of the firm. This is in line with other research on voluntary vs. involuntary exits (DeTienne & Wennberg, 2016).

The failure curve does not seem to really flatten out at any point, with failures occurring at 14 years and beyond. However, only the oldest cohorts in the portfolio had the opportunity to mature to such an age. Consequently, interpretation is somewhat difficult beyond 10 to 12 years due to the limited number of observations. Nevertheless, the analysis indicates that ASOs have very long development processes before reaching terminal outcomes.

Trade sales seem to be a very important outcome, with approximately 10% of ASOs expected to be acquired within 10 years. A trade sale is defined here by two criteria adopted from the technology acquisition literature (Puranam et al., 2003): (1) the buyer is an industry incumbent significantly larger than the new venture; and (2) the buyer assumes 51% or more ownership (stock sale) or all productive assets (asset sale). Perhaps surprisingly, Figure 5.8 illustrates that trade sales occur quite steadily from a very young age. A closer qualitative inspection reveals the following conditions at the time of the trade sale:

- The majority of ASOs are very small: 72% have five employees or less, 55% have less than 3 MNOK in revenue and 80% are unprofitable.
- Only four firms have over 10 employees and three firms have above 20 MNOK in revenue. One firm represents approximately 43% of all revenue and employees.
- Seven firms have an acquisition valuation above 50 MNOK, and one firm represents more than half of the (known) acquisition value in the portfolio (valuation of approx. 500 MNOK.

In fact, only approximately one-third of the trade sales can be understood as having a substantial value exchange between buyer and seller. The majority of ASOs pursuing a trade sale seem to use it as a mechanism to further develop their technology and business concept in an industrial context. Although acquisitions by large foreign companies do occur in the portfolio, the majority of buyers were domestic firms. Furthermore, many of the ASOs acquired by foreign companies remained domestically, and even increased the scope of their business activities locally.

An initial public offering (IPO) is a non-terminal outcome, and is often viewed as a financial performance event. IPOs are rare outcomes of academic entrepreneurship in Norway, but still represent a major source of firm value in the portfolio. Four ASOs went public on the Oslo Stock Exchange during the observation period, in which three are pharmaceutical drug development companies. Two ASOs were later delisted and remain privately owned with modest valuations. The remaining two ASOs have current valuations of approximately 5 billion NOK (approx. €550M), with one firm (Nordic Nanovector) representing 90% of the total value. Again, a very skewed distribution is observed. More importantly, the valuation of Nordic Nanovector grew aby approximately 700% in 2016 as the market responded to positive results from the firm's clinical trials. As is commonplace in a pharmaceutical context, Nordic Nanovector has still not experienced any significant commercial revenue (Gilbert et al., 2006).

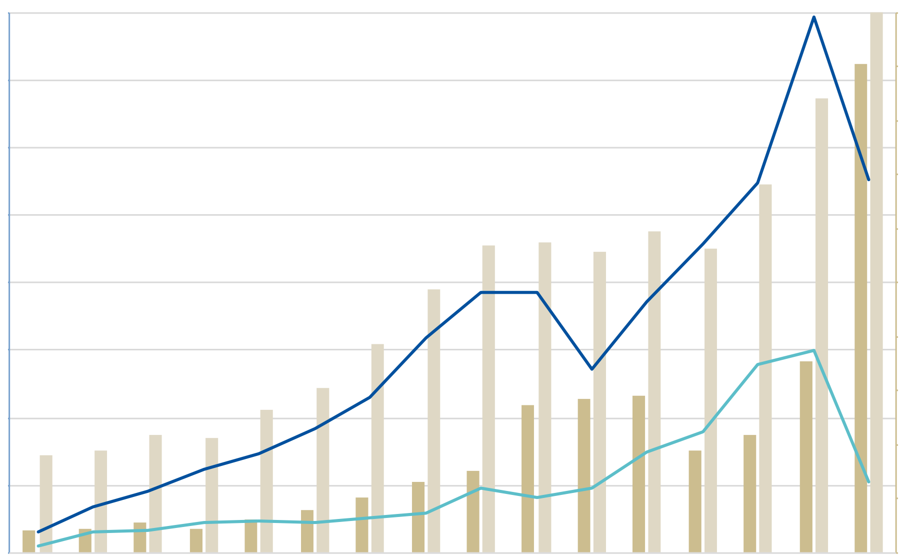
Firm growth – revenues

Firms that fail cannot grow, but survival is not necessarily evidence for growth in the context of academic entrepreneurship. Looking first at revenue, Figure 5.9 shows the development in revenue from founding (ASOs are included in the analysis until reaching a terminal outcome).

The mean is always higher than the median revenue, indicating that the distribution of revenue is skewed to the right. The bars show the share of the largest firms over time, illustrating that a small number of ASOs are responsible for a large share of total revenue. Over time, the distribution becomes more skewed and, after 10 years, the highest grossing firm represents over one-fourth of total revenue. A more detailed investigation of the distribution finds that very low revenues (i.e. below NOK 500,000) are most common, regardless of firm age. Three ASOs have experienced revenues above 100 MNOK, and four additional firms above MNOK 50.

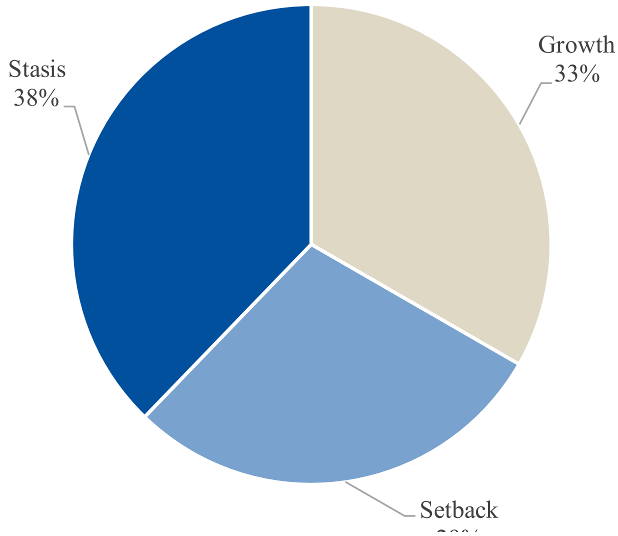
While it seems clear that a few ASOs will dominate total revenue generated over time, it does not provide insight into how growth occurs on the firm level. Most ASOs do not seem to grow at all, but growth spurts from certain firms ensure that the average annual growth remains positive. Yet, Figure 5.9 shows that growth setbacks also occur. Taken together, this indicates that "stasis" (Derbyshire & Garnsey, 2014), i.e., no growth, may be a common growth scenario accompanied by discontinuous and erratic growth events in certain ASOs (Coad, 2007, 2010; Garnsey & Heffernan, 2005):

Figure 5.9: Development in revenues (mean and median; thousands NOK) in years since establishment (lines; measured on left axis). Share of total represented by the largest and five largest firms (bars; measured on right axis).



To investigate this in more detail, each annual growth period was coded as "Growth", "Stasis", or "Setback" according to the method outlined by Coad et al. (2015). Figure 5.10 shows that all three types of annual growth are approximately as frequent, with Stasis being slightly more frequent at 38%:

Figure 5.10: Distribution of growth type on annual basis in the portfolio

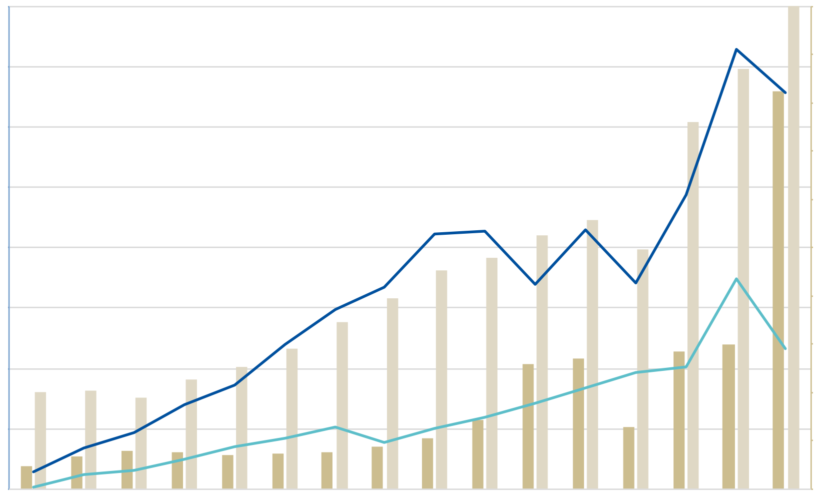


Firm growth – employment

In certain new venture scenarios, employment will precede revenue growth, and thus be a more useful indicator of growth (Delmar et al., 2003; Knockaert et al., 2011). For instance, ASOs commercializing new pharmaceutical drugs often go for many years without any sales (Gilbert et al., 2006). Figure 5.11 shows the development in labour cost in the portfolio. Labour cost is preferred here over a number of employees because of its more granular nature and automatically accounting for part-time positions.

It is fair to say that employment follows a similar development as revenues, in which a few ASOs go on to represent the majority of employment over time. Revenue and labour cost are also highly correlated ($r = 0.85$, strongly statistically significant), indicating that to a large extent the biggest employers are the same ASOs with the highest revenues (similar result to Shepherd and Wiklund (2009)). Most ASOs have very few employees (a median increase of one to four employees for the oldest firms), with only seven ASOs having more than 30 employees at any one time. The largest number of employees observed for any ASO was 78. Comparable to revenues, most ASOs have no growth in employment. However, employment and revenue differ with respect to the dynamics of growth. Labour cost exhibits very strong serial correlation ($r = 0.94$, strongly statistically significant). This indicates that growth in employment is highly path-dependent, with less variability and erratic patterns compared with revenue growth:

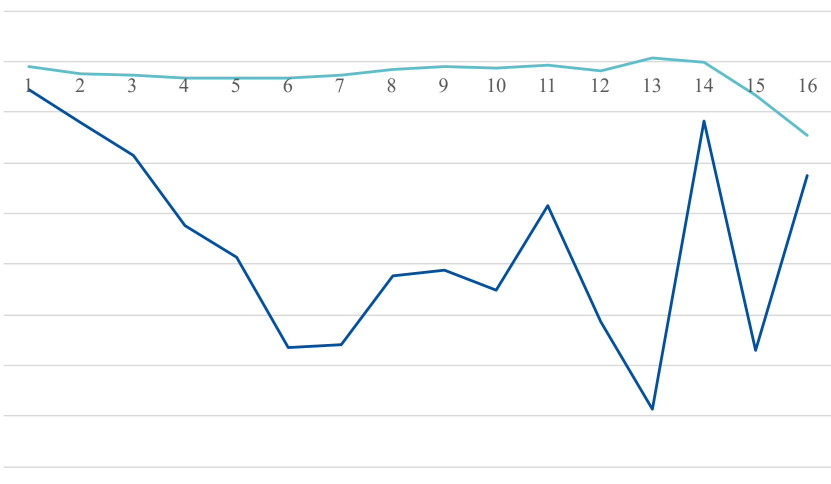
Figure 5.11: Development in labour cost (mean and median; thousands NOK) in years since establishment (lines; measured on left axis). Share of total represented by the largest and five largest firms (bars; measured on right axis).



Firm growth - profitability

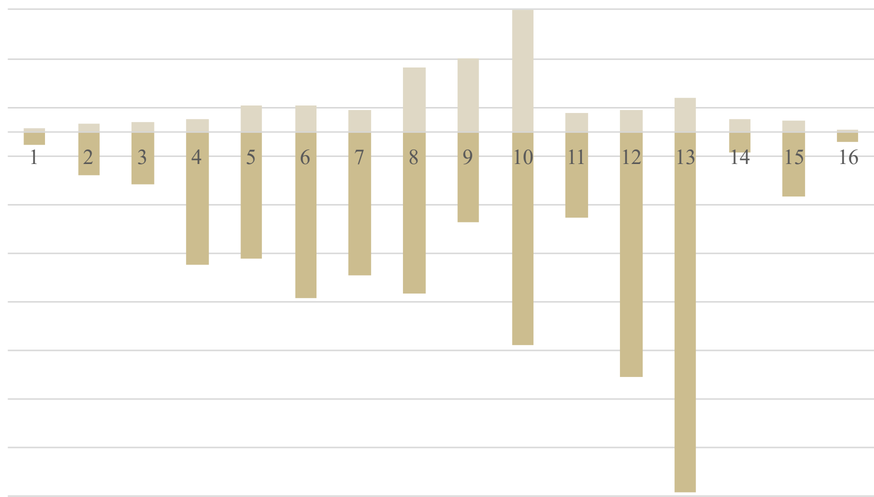
Sooner or later, the objective of all independent firms, is to make a profit. However, losses frequently occur in the period when technologies are developed into marketable products and services. Figure 5.12 shows the development in operating result (earnings before interest and taxes, EBIT) from founding:

Figure 5.12: Development in operating result (mean and median) in years since establishment (thousands NOK)



Most ASOs sustain consistent negative, but very small losses. The major difference between the mean and median indicates a skewed distribution, and that some ASOs run major operational losses. Figure 5.13 shows the extreme values (max/min) of operating result at each firm age.

Figure 5.13: Maximum and minimum operating result (thousands NOK)



While profits above 10 MNOK occur from around year five, losses are far more frequent and substantial. Starting in year four, the activities of certain ASOs generate losses in excess of 50 MNOK. More detailed insight was obtained from analyzing the ASOs at both ends of the profitability extremes. First, the ASOs achieving the highest profits generally do so after running losses (and often quite substantial ones) in earlier years. These ASOs have successfully commercialized their technology, and have been able to grow revenues to a point where sustainable profitable operations have commenced. In particular, one ASO has the three highest years of operating result observed in the portfolio, supporting earlier findings of the large impact of a few ASOs.

A further analysis of operating results over time reveals that several growth trajectories can lead to profitability. Since their founding, two of the most profitable ASOs (in accumulative terms) have created consistent, but moderate, positive profits for the last 15 years. Interestingly, both ASOs offer consulting services based on unique scientific expertise. In other words, these ASOs are not only commercializing specific inventions. Hence, while the highest profits are not generated from these service-based business models, profitability can be achieved much more quickly.

Moreover, the ASOs generating the highest losses generally have major operating costs other than employment. Many of these ASOs are developing new pharmaceutical drugs, and these costs presumably relate to clinical trials and other development expenses.
To be clear, employment costs are always present, but they are not the main contributor to the high operating costs in these cases. The ASOs in question are obviously able to sustain such losses because of success in raising substantial VC capital. Thus, from one

perspective, these are highly unprofitable firms. But from another perspective, these are the same firms receiving high valuations, and viewed as the most promising new ventures in the portfolio. The ambition of both entrepreneurs and investors is future high profits or high value IPOs and/or trade sales. This counterintuitive fact is a distinctive characteristic of this portfolio of ASOs (Rasmussen & Mathisen, 2017).

5.5 Conclusion and implications

This chapter has presented a comprehensive analysis of Norwegian ASOs, investigating their origins, development, growth and ultimate outcomes. In conclusion, three areas seem particularly important for policymakers. First, commercialization can occur through qualitatively different outcomes; therefore, focusing only on simple or singular performance outcomes will likely have major limitations. While a firm might appear to be unsuccessful in one facet of performance (e.g. profits), it might simultaneously be highly successful in another (e.g. firm value). For instance, trade sales with very high valuations do occur, and more generally, trade sales seem to be an important mechanism to access the necessary resources to successfully scale-up commercialization processes. Assuming the survival of an independent firm as a precondition for success is thus misguided. In addition, trade sales often have unfavourable connotations in policy circles because of the fear that technologies and firms partly financed by governmental resources and tax dollars will be "sold of the country", thus surrendering the new knowledge-based employment opportunities which would be created locally. Although acquisitions by large foreign companies do occur, the majority of buyers in the portfolio were domestic firms. And many, if not most, of the ASOs acquired by foreign companies remained domestically, and even increased the scope of their business activities locally. Successful trade sales also provide high returns for entrepreneurs and VC investors, which can then be re-invested into new ventures. For these reasons, policymakers should keep an open mind with respect to trade sales. More specifically, policymakers should facilitate for large foreign industry incumbents to interact with domestic PROs for the mutual benefit of both parties.

Second, skewed distributions and the extreme impact of outliers appear to be the norm across most dimensions of the ASO phenomenon. Under these circumstances, interpreting average values should be done with care as they are mostly misleading. A meaningful evaluation of a portfolio of ASOs must therefore pay particular attention to the portfolio's outliers and not only its most common members. This is a general feature of all science commercialization, including patenting and licencing.

Finally, the time needed for the commercialization of research is very long, and development and growth can be discontinuous and erratic. The timing of evaluation matters a great deal as the status and prospects of ASOs can be dramatically changed over short periods. For example, in the days preparing this chapter, the portfolio company Ultimovacs went public on the Oslo Stock Exchange with a valuation of over 500 million NOK. These findings are fully compatible with phenomena characterized by a high uncertainty and skewed outcomes such as ASOs demonstrably are.

Bibliography

Agrawal, A. (2001). University-to-industry knowledge transfer: literature review and unanswered questions. International Journal of Management Reviews 2001;3:285-302.

Bjørnåli, E. S., & Aspelund, A. (2012). The role of the entrepreneurial team and the board of directors in the internationalization of academic spin-offs. Journal of International Entrepreneurship 2012;10:350-377.

Borlaug, S. B., Grunfeld, L., Gulbrandsen, M., Rasmussen, E., Rønning, L., & Spilling, O.R. et al. (2009.) Between entrepreneurship and technology transfer: Evaluation of the FORNY programme. NIFU STEP; 2009.

Bozeman, B. (2000). Technology transfer and public policy: A review of research and theory. Research Policy 2000;29:627-655.

Bozeman, B., Fay, D., & Slade, C. P. (2013). Research collaboration in universities and academic entrepreneurship: The-state-of-the-art. Journal of Technology Transfer 2013;38:1-67.

Brander, J. A., Du, Q., & Hellmann, T. (2014). The effects of government-sponsored venture capital: International evidence. Review of Finance 2014:rfu009.

Chiesa, V., & Piccaluga, A. (2000). Exploitation and diffusion of public research: The case of academic spin-off companies in Italy. R & D Management 2000;30:329-339.

Clarysse, B., & Moray, N. (2004). A process study of entrepreneurial team formation: The case of a research-based spin-off. Journal of Business Venturing 2004;19:55-79.

Clarysse, B., Wright, M., Lockett, A., Mustar, P., & Knockaert, M. (2007). Academic spin-offs, formal technology transfer and capital raising. Industrial and Corporate Change 2007;16:609-640.

Clarysse, B., Wright, M., Lockett, A., Van de Velde, E., & Vohora, A. (2005). Spinning out new ventures: A typology of incubation strategies from European research institutions. Journal of Business Venturing 2005;20:183-216.

Clausen, T. H., & Rasmussen, E. (2013). Parallel business models and the innovativeness of research-based spin-off ventures. Journal of Technology Transfer 2013:1-14.

Coad, A. (2007). A closer look at serial growth rate correlation. Review of Industrial Organization 2007;31:69-82.

Coad, A. (2010). Exploring the processes of firm growth: Evidence from a vector auto-regression. Industrial and Corporate Change 2010;19:1677-1703.

Coad, A., Frankish, J. S., Roberts, R. G., & Storey, D. J. (2015). Are firm growth paths random? A reply to "Firm growth and the illusion of randomness". Journal of Business Venturing Insights 2015;3:5-8.

Colombo, M., Mustar, P., & Wright, M. (2010). Dynamics of Science-based entrepreneurship. Journal of Technology Transfer 2010;35:1-15.

Criaco, G., Minola, T., Migliorini, P., & Serarols-Tarrés, C. (2014). "To have and have not": Founders' human capital and university start-up survival. Journal of Technology Transfer 2014:1-27.

Delmar, F., Davidsson, P., & Gartner, W. B. (2003). Arriving at the high-growth firm. Journal of Business Venturing 2003;18:189-216.

Derbyshire, J., & Garnsey, E. (2014). Firm growth and the illusion of randomness. Journal of Business Venturing Insights 2014;1:8-11.

DeTienne, D., & Wennberg, K. (2016). Studying exit from entrepreneurship: New directions and insights. International Small Business Journal 2016;34:151-156.

Djokovic, D., & Souitaris, V. (2008). Spinouts from academic institutions: A literature review with suggestions for further research. Journal of Technology Transfer 2008;33:225-247.

Ensley, M. D., & Hmieleski, K. A. (2005). A comparative study of new venture top management team composition, dynamics and performance between university-based and independent start-ups. Research Policy 2005;34:1091-1105.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. Research Policy 2000;29:109-123.

Etzkowitz, H., Webster, A., Gebhardt, C., & Terra, B. R. C. (2000). The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm. Research Policy 2000;29:313-330.

Fini, R., Fu, K., Mathisen, M. T., Rasmussen, E., & Wright, M. (2017). Institutional determinants of university spin-off quantity and quality: A longitudinal, multilevel, cross-country study. Small Business Economics 2017;48:361-391.

Fini, R., Rasmussen, E., Siegel, D., & Wiklund, J. (2018). Rethinking the Commercialization of Public Science: From Entrepreneurial Outcomes to Societal Impacts. Academy of Management Perspectives 2018;32:4-20.

Fontes, M. (2005). The process of transformation of scientific and technological knowledge into economic value conducted by biotechnology spin-offs. Technovation 2005;25:339-347.

Garnsey, E., & Heffernan, P. (2005). Growth setbacks in new firms. Futures 2005;37:675-697.

Geuna, A., & Muscio, A. (2009). The Governance of University Knowledge Transfer: A Critical Review of the Literature. Minerva 2009;47:93-114.

Gilbert, B. A., McDougall, P. P., & Audretsch, D. B. (2006). New venture growth: A review and extension. Journal of Management 2006;32:926-950.

Goldfarb, B., & Henrekson, M. (2003). Bottom-up versus top-down policies towards the commercialization of university intellectual property. Research Policy 2003;32:639-658.

Golob, E. (2006). Capturing the regional economic benefits of university technology transfer: A case study. Journal of Technology Transfer 2006;31:685-695.

Grimaldi, R., Kenney, M., Siegel, D. S., & Wright, M. (2011). 30 years after Bayh-Dole: Reassessing academic entrepreneurship. Research Policy 2011;40:1045-1057.

Grünfeld, L. A., Teie, M. G., Hvide, H., Spilling, O. R., & Borlaug, S. B. (2018). Insentiver For Kommersialisering Av Forskning. 2018.

Gulbrandsen, M. (2011). Research institutes as hybrid organizations: Central challenges to their legitimacy. Policy Sciences 2011;44:215-230.

Hall, B., Helmers, C., Rogers, M., & Sena, V. (2014). The Choice between Formal and Informal Intellectual Property: A Review. Journal of Economic Literature 2014;52:375-423.

Harrison, R. T., & Leitch, C. (2010). Voodoo Institution or Entrepreneurial University? Spin-off Companies, the Entrepreneurial System and Regional Development in the UK. Regional Studies 2010;44:1241-1262.

Hayter, C. S. (2011). In search of the profit-maximizing actor: Motivations and definitions of success from nascent academic entrepreneurs. Journal of Technology Transfer 2011;36:340-352.

Hayter, C. S. (2016a). Constraining entrepreneurial development: A knowledge-based view of social networks among academic entrepreneurs. Research Policy 2016a;45:475-490.
Hayter, C. S. (2016b). A trajectory of early-stage spinoff success: The role of knowledge intermediaries within an entrepreneurial university ecosystem. Small Business Economics 2016b;47:633-656.
Heirman, A., & Clarysse, B. (2004). How and why do research-based start-ups differ at founding? A resource-based configurational perspective. Journal of Technology Transfer 2004;29:247-268.
Hindle, K., & Yencken, J. (2004). Public research commercialisation, entrepreneurship and new technology based firms: An integrated model. Technovation 2004;24:793-803.
Hurmelinna- Laukkanen, P., & Puumalainen, K. (2007). Nature and dynamics of appropriability: Strategies for appropriating returns on innovation. R&D Management 2007;37:95-112.
Huyghe, A., & Knockaert, M. (2015). The influence of organizational culture and climate on entrepreneurial intentions among research scientists. Journal of Technology Transfer 2015;40:138-160.
Hvide, H. K., & Jones, B. F. (2018). University Innovation and the Professor's Privilege. American Economic Review 2018;108:1860-1898.
Karnani, F. (2013). The university's unknown knowledge: Tacit knowledge, technology transfer and university spin-offs findings from an empirical study based on the theory of knowledge. Journal of Technology Transfer 2013;38:235-250.
Kirchberger, M. A., & Pohl, L. (2016). Technology commercialization: A literature review of success factors and antecedents across different contexts. The Journal of Technology Transfer 2016:1-36.
Knockaert, M., Ucbasaran, D., Wright, M., & Clarysse, B. (2011). The Relationship between Knowledge Transfer, Top Management Team Composition, and Performance: The Case of Science-Based Entrepreneurial Firms. Entrepreneurship Theory and Practice 2011;35:777-803.
Kochenkova, A., Grimaldi, R., & Munari, F. (2016). Public policy measures in support of knowledge transfer activities: A review of academic literature. Journal of Technology Transfer 2016;41:407-429.
Lawton Smith, H., Romeoa, S., & Bagchi-Senb, S. (2008). Oxfordshire biomedical university spin-offs: An evolving system. Cambridge Journal of Regions, Economy and Society 2008;1:303-319.
Leitch, C., Hill, F., & Neergaard, H. (2010). Entrepreneurial and Business Growth and the Quest for a "Comprehensive Theory": Tilting at Windmills? Entrepreneurship Theory and Practice 2010;34:249-260.
Link, A. N., Siegel, D. S., & Bozeman, B. (2007). An empirical analysis of the propensity of academics to engage in informal university technology transfer. Industrial and Corporate Change 2007;16:641-655.
Lubik, S., & Garnsey, E. (2016). Early Business Model Evolution in Science-based Ventures: The Case of Advanced Materials. Long Range Planning 2016;49:393-408.
Lundqvist, M. A. (2014). The importance of surrogate entrepreneurship for incubated Swedish technology ventures. Technovation 2014;34:93-100.
Markman, G. D., Siegel, D. S., & Wright, M. (2008). Research and Technology Commercialization. Journal of Management Studies 2008;45:1401-1423.
Mathisen, M. T. (2017). The Growth of Research-Based Spin-Offs: Unleashing the Value of Academic Entrepreneurship. Department of Industrial Economics and

Technology Management. Trondheim, Norway: Norwegian University of Science and Technology; 2017.

Mathisen, M. T., & Rasmussen, E. (2019). The development, growth, and performance of university spin-offs: A critical review. The Journal of Technology Transfer 2019:1-48.

Mervis, J. (2016). When the payoff for academics drops, commercialization suffers. American Association for the Advancement of Science; 2016.

Mian, S., Lamine, W., & Fayolle, A. (2016). Technology Business Incubation: An overview of the state of knowledge. Technovation 2016;50-51:1-12.

Mohr, V., & Garnsey, E. (2011). How do high-growth firms grow? Evidence from Cambridge, UK. Economics, Management and Financial Markets 2011;6:29.

Moray, N., & Clarysse, B. (2005). Institutional change and resource endowments to science-based entrepreneurial firms. Research Policy 2005;34:1010-1027.

Mowery, D. C. (2011). Learning from one another? International policy "emulation" and university-industry technology transfer. Industrial and Corporate Change 2011;20:1827-1853.

Mustar, P., Renault, M., Colombo, M. G., Piva, E., Fontes, M., & Lockett, A. et al. (2006). Conceptualising the heterogeneity of research-based spin-offs: A multi-dimensional taxonomy. Research Policy 2006;35:289-308.

Mustar, P., Wright, M., & Clarysse, B. (2008). University spin-off firms: Lessons from ten years of experience in Europe. Science and Public Policy 2008;35:67-80.

O'Shea, R. P., Chugh, H., & Allen, T. J. (2008). Determinants and consequences of university spinoff activity: A conceptual framework. Journal of Technology Transfer 2008;33:653-666.

Patzelt, H., & Shepherd, D. A. (2009). Strategic Entrepreneurship at Universities: Academic Entrepreneurs' Assessment of Policy Programs. Entrepreneurship Theory and Practice 2009;33:319-340.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Brostrom, A., & D'Este, P. et al. (2013). Academic engagement and commercialisation: A review of the literature on university-industry relations. Research Policy 2013;42:423-442.

Phan, P. H., Siegel, D. S., & Wright, M. (2005). Science parks and incubators: Observations, synthesis and future research. Journal of Business Venturing 2005;20:165-182.

Pirnay, F., Surlemont, B., & Nlemvo, F. (2003). Toward a typology of university spin-offs. Small Business Economics 2003;21:355-369.

Pries, F., & Guild, P. (2007). Commercial exploitation of new technologies arising from university research: Start-ups and markets for technology. R & D Management 2007;37:319-328.

Puranam, P., Singh, H., & Zollo, M. (2003). A bird in the hand or two in the bush?: Integration trade-offs in technology-grafting acquisitions. European Management Journal 2003;21:179-184.

Rasmussen, E., Borlaug, S. B., Bulanova, O., Clausen, T., Spilling, O.R., & Sveen, T. (2013). Verdiskaping i forskningsbaserte selskaper og lisenser støttet av FORNY-programmet. 2013.

Rasmussen, E., Bulanova, O., Jensen ,A., & Clausen, T. (2016). The Impact of Science-Based Entrepreneurial Firms - a Literature Review and Policy Synthesis. Bodø: University of Nordland; 2016.

Rasmussen, E., & Mathisen, M. T. (2017). Science-based Entrepreneurial Firms as Real Options: Assessing the Outcomes of the Norwegian Firm Population from 1995 to 2012. In R. Fini & R. Grimaldi (Eds.), Process Approach

to Academic Entrepreneurship: Evidence from the Globe. World Scientific Reference; 2017.
Rasmussen, E., Moen, O., & Gulbrandsen, M. (2006). Initiatives to promote commercialization of university knowledge. Technovation 2006;26:518-533.
Rasmussen, E., Mosey, S., & Wright, M. (2015). The transformation of network ties to develop entrepreneurial competencies for university spin-offs. Entrepreneurship and Regional Development 2015;27:430-457.
Rasmussen, E., Sørheim, R., & Widding, L. (2007). Gjennomgang av virkemidler for kommersialisering av forskningsresultater (Assessment of government supports schemes for the commercialization of research) Bodø. Norway: Bodø Graduate School of Business; 2007.
Renault, C. S. (2006). Academic capitalism and university incentives for faculty entrepreneurship. Journal of Technology Transfer 2006;31:227-239.
Rothaermel, F. T., Agung, S. D., & Jiang, L. (2007). University entrepreneurship: A taxonomy of the literature. Industrial and Corporate Change 2007;16:691-791.
Rothaermel, F. T., & Thursby, M. (2005). Incubator firm failure or graduation? The role of university linkages. Research Policy 2005;34:1076-1090.
Salvador, E. (2011). Are science parks and incubators good "brand names" for spin-offs? The case study of Turin. Journal of Technology Transfer 2011;36:203-232.
Schumpeter, J. A. (1934). The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle. Transaction Publishers; 1934.
Scrucca, L., Santucci, A., & Aversa, F. (2007). Competing risk analysis using R: An easy guide for clinicians. Bone Marrow Transplantation 2007;40:381-387.
Shane, S. (2001a). Technological opportunities and new firm creation. Management Science 2001a;47:205-220.
Shane, S. (2001b). Technology regimes and new firm formation. Management Science 2001b;47:1173-1190.
Shane, S. (2004a). Academic Entrepreneurship University Spinoffs and Wealth Creation. Cheltenham, UK: Edward Elgar Publishing; 2004a.
Shane, S. (2004b). Encouraging university entrepreneurship? The effect of the Bayh-Dole Act on university patenting in the United States. Journal of Business Venturing 2004b;19:127-151.
Shepherd, D., & Wiklund, J. (2009). Are We Comparing Apples With Apples or Apples With Oranges? Appropriateness of Knowledge Accumulation Across Growth Studies. Entrepreneurship Theory and Practice 2009;33:105-123.
Siegel, D. S., Veugelers, R., & Wright, M. (2007a). Technology transfer offices and commercialization of university intellectual property: Performance and policy implications. Oxford Review of Economic Policy 2007a;23:640-660.
Siegel, D. S., Wright, M., & Lockett, A. (2007b). The rise of entrepreneurial activity at universities: Organizational and societal implications. Industrial and Corporate Change 2007b;16:489-504.
Slaughter, S., & Rhoades, G. (2004). Academic capitalism and the new economy: Markets, state, and higher education. JHU Press; 2004.
Spilling, O. R., Borlaug, S. B., Iversen, E. J., Rasmussen, E., & Solberg, E. (2015). Virkemiddelapparatet for kommersialisering av forskning–status og utfordringer: Sluttrapport fra evalueringen av virkemiddelapparatet for kommersialisering av offentlig finansiert forskning. 2015.
Stuart, T. E., & Ding, W. W. (2006). When do scientists become entrepreneurs? The social structural antecedents of commercial activity in the academic life sciences. American Journal of Sociology 2006;112:97-144.

Thumm, N. (2004). Strategic patenting in biotechnology. Technology Analysis & Strategic Management 2004;16:529-538.

Van Looy, B., Landoni, P., Callaert, J., van Pottelsberghe, B., Sapsalis, E., & Debackere, K. (2011). Entrepreneurial effectiveness of European universities: An empirical assessment of antecedents and trade-offs. Research Policy 2011;40:553-564.

Vincett, P. S. (2010). The economic impacts of academic spin-off companies, and their implications for public policy. Research Policy 2010;39:736-747.

Walter, A., Auer, M., & Ritter, T. (2006). The impact of network capabilities and entrepreneurial orientation on university spin-off performance. Journal of Business Venturing 2006;21:541-567.

Wright, M., Clarysse, B., Mustar, P., & Lockett, A. (2007). Academic Entrepreneurship in Europe. Cheltenham, UK: 'Edward Elgar Publishing, Inc.'; 2007.

Wright, M., Lockett, A., Clarysse, B., & Binks, M. (2006). University spin-out companies and venture capital. Research Policy 2006;35:481-501.

Zhang, J. F. (2009). The performance of university spin-offs: An exploratory analysis using venture capital data. Journal of Technology Transfer 2009;34:255-285.

6. Entrepreneurship education and its impacts

This chapter presents the main findings from the literature on entrepreneurship education. We first introduce and explore the foundations and philosophy of entrepreneurship education, illustrating how it has evolved from a focus on new venture creation to an individual-centric view. The second section of this chapter focuses on the organization of entrepreneurship education, viewing both curricular and extra-curricular developments. In this section, we also use several examples developed by NTNU in order to illustrate how entrepreneurship education activities could be organized. The last section will focus on the assessment of entrepreneurship education, in which contemporary approaches and designs of assessment are presented. This section also points to some of the identified issues with the current practices and literature on this topic. The chapter's key takeaways are then summarized in the last section.

6.1. Main trends in entrepreneurship education

Since its early introduction in the 1970s, entrepreneurship education has been growing in numbers (Katz, 2003; Kuratko, 2005) and in its approaches to educational design (Aadland & Aaboen, 2018; Hägg & Gabrielsson, 2019; Mwasalwiba, 2010). While the early offerings focused on new venture creation and small business development (McMullan & Long, 1987), and were mostly found in the universities' business departments (Gartner & Vesper, 1994), entrepreneurship is now a cross-campus initiative established in a number of departments, e.g., engineering (Creed et al., 2002; da Silva et al., 2015; Standish-Kuon & Rice, 2002), nursing and pharmacy (Boore & Porter, 2011; Shahiwala, 2017) and publishing (Faherty, 2015).

The focus of the education has also changed into a more holistic view, in which the entrepreneurial mind-set and the idea of graduates contributing in a broader sense than simply new venture creation has grown (Blenker et al., 2011; Neck & Greene, 2011). With this view, changes in the educational approaches have also occurred at a rapid tempo, developing into a more student-centred focus (Aadland & Aaboen, 2018; Hägg & Gabrielsson, 2019). This approach could include collaboration and internship with established companies (Saukkonen et al., 2016), business simulation (Pittaway & Cope, 2007b) and student-TTO collaborations and venture creation (Lackéus & Williams Middleton, 2015; Siegel & Wright, 2015). As such, the students' role has changed, not only from a passive knowledge receiver to a self-directed individual in an educational sense, but to obtaining a more central role in the entrepreneurial-university context as well. The role and activities for students in the university context is also central in the development of an entrepreneurial ecosystem, and for fostering entrepreneurial activities (Wright et al., 2017).

However, while entrepreneurship education now spans a broader range in terms of outcomes, approaches and disciplines, the primary goal of introducing entrepreneurship to students through education is the idea that this will foster economic growth and regional development (O'Connor, 2013). As mentioned, the means to reach this end do differ, from new venture creation and growth, through developing entrepreneurial skills, to changing attitudes, culture and spirit (Mwasalwiba, 2010). For example, engineering students are introduced to entrepreneurship education, since entrepreneurial attitude and skills are seen as important for the innovating activities these students and graduates are taking part in (Oswald Beiler, 2015; Yi & Duval-Couetil, 2018). Hence, from this overarching objective to the programme and course-specific objectives, and with the various approaches and designs in entrepreneurship education, the interest and literature on the assessment of courses and programmes has also seen a massive increase in later years (Longva & Foss, 2018; Nabi et al., 2017).

6.2 Foundations and Contemporary Focus of Entrepreneurship Education

As previously stated, entrepreneurship education has gone from being a business school offering focusing on new venture creation, to becoming a cross-disciplinary initiative aiming at changing the mind-set of its enrolled students. With this development, the educational philosophy in the field has also changed, and to a large degree removed itself from tangential education (e.g. management and business) and become entrepreneurial itself (Neck & Greene, 2011). The view has become more holistic, focusing on the individual's mind-set rather than new venture creation, and student-centred education rather than teacher-directed approaches (Aadland & Aaboen, 2018; Hägg & Gabrielsson, 2019).

The early literature described entrepreneurship education organized in the business schools and focused on new venture creation, which was the optimal outcome (McMullan & Long, 1987). The literature then followed this view, and presented educational approaches in the direction of the entrepreneurial process (Gartner & Vesper, 1994; Plaschka & Welsch, 1990). However, the focus later changed somewhat to the individual as an entrepreneur. This might also be as a result of a growing interest among European scholars, which had a broader view on entrepreneurship (and enterprise) compared to their North American colleagues (Hägg & Gabrielsson, 2019). While the latter view entrepreneurship as self-employment and the initiation of new ventures, the European scholars focus more on attitudes and behaviour in both new venture creation and small businesses (Hägg & Gabrielsson, 2019). In particular, the learning and development of the individual as an entrepreneur became more prominent (e.g. Jones & English, 2004; Pittaway & Cope, 2007b; Shepherd, 2004). This trend continued into the 2010s, although the view of an entrepreneur in entrepreneurship education became broader than in previous literature, as the entrepreneur might contribute to different situations other than new ventures and small businesses (Blenker et al., 2011), but also in that new terms such as social entrepreneurship appeared (Pache & Chowdhury, 2012).

In later years, the view of entrepreneurs as individuals who contribute in different situations has stood forth in the literature, especially on the European side of the field. The idea that the competences used by entrepreneurs are applicable in different disciplines has become evident, with the idea of life-long learning through entrepreneurship being central in the field (Hägg & Kurczewska, 2016). A growing literature is also exploring the outcomes from educations in terms of an entrepreneurial mind-set (e.g. Lindberg et al., 2017), often defined as deep cognitive structures which are altered and developed through experiences with entrepreneurship (Krueger, 2007). As such, learning through experiences is a central topic in contemporary entrepreneurship education, and the concept of entrepreneurial learning has been supported and applied as a framework in understanding the approaches used in action-based entrepreneurship education (Hägg & Kurczewska, 2016).

Entrepreneurial learning build on Kolb's (1984) theory of experiential learning (e.g. Politis, 2005); therefore, reflections have also obtained a central place in entrepreneurship education (Hägg & Kurczewska, 2016), which stands in contrast from the view found in the early literature on entrepreneurship education. Thus, it is through the mind-set that entrepreneurship is obtaining a growing acceptance in other disciplines, and where entrepreneurship previously was (and in some instances still is) considered a business and new venture activity, the focus has shifted into a broad and narrow view (Hoppe et al., 2017). The narrow view still follows the North American view that entrepreneurship is about creating new ventures (Neck & Corbett, 2018); however, the broad view aims more at entrepreneurial competences and value creation (Hoppe et al., 2017), and as a result has developed innovative and entrepreneurial individuals independent of their discipline. For instance, Boore and Porter (2011, p. 191) state that "Nurses in any area of practice and at any level will be able to make a valuable contribution to health care if they demonstrate the characteristics and skills of the entrepreneur." The same is found in the publishing discipline, in which changes and development in the industry has demanded a call for more enterprise and entrepreneurial skills among future graduates (Faherty, 2015) or among engineers, who are continuously challenged in being innovative and creating new value (da Silva et al., 2015).

Entrepreneurship education is explained above and is recognized as more than simply new venture creation, and as universities are to a growing degree introducing entrepreneurship to their students, new ways of designing entrepreneurship education and embedding it in courses or programmes have emerged. However, while the concepts are getting broader, the approaches and designs of such educations are more difficult to follow than ever. The next section will therefore explore educational approaches and designs from a narrow to a broad view, but also introduce the ideas of extra-curricular activities, as these are becoming more important for students in higher education.

6.3 Organizing Entrepreneurship Education in Higher Education

Because entrepreneurship is moving into different departments and faculties, a central question is how to design relevant teaching forms of entrepreneurship. In their research, Warhuus and Basaiawmoit (2014) found a difference in centralization or decentralization of the programmes investigated, in addition to a connection between the number of credits offered in the programmes and the number of students they reached. In terms of centralization, one department delivers the educational offering to different disciplines, either as a stand-alone course (Wilson, 2008) or through collaborative efforts in which business departments deliver modules or lectures in the courses (e.g. Hynes, 1996). Otherwise, the offering is placed at the different departments (Handscombe et al., 2008), but might require champions to drive the courses and bring their development forth (Wilson, 2008).

However, examples of courses developed as joint efforts between different departments are also present, such as the WOFIE course at Aalborg University (McDonald et al., 2018). The different courses could also be small or big in terms of the number of students, independent of being centralized or a department-specific offer (Warhuus & Basaiawmoit, 2014), but as also noted fewer students might obtain a higher amount of credits. This is a result of the resource demand some education requires (Aadland & Aaboen, 2018;

Mwasalwiba, 2010), e.g., through the venture creation activity and strategic collaboration this demands (Lackéus & Williams Middleton, 2015; Rasmussen & Sørheim, 2006), or through their own incubators for the education's students (Warhuus & Basaiawmoit, 2014). Hence, a balance is required, which could be the reason some education still applies a more traditional approach to entrepreneurship education and teaching about entrepreneurship (Aadland & Aaboen, 2018; Mwasalwiba, 2010), but still with an objective of creating entrepreneurial individuals.

Box 6.1 Entrepreneurship education organization in the Nordics – examples

In a recent study by Aadland and Aaboen (n.d.), 10 Nordic technical universities were explored in terms of their educational efforts in entrepreneurship. Two universities from each country were included and three to four teacher and course managers at each site were interviewed, in addition to a collection of resources from web sources. As illustrated in Table 1 below, the findings show that the different countries applied different designs and approaches to their offering of entrepreneurship education. While the Scandinavian and Islandic universities offered programmes in entrepreneurship, Finland appears to only focus their effort in centralized "hubs", where either independent, non-academic departments or specific departments organized the offerings. In addition, while none of these universities had prominent programmes, they still offered minors or majors in entrepreneurship for their students. However, while the other universities in the other countries did not have a similar prominent hub, in the majority of cases they organized their offerings from one department. Some of the universities offered courses to all students (often mandatory), while others had more specialized courses designed for the intended disciplines.

Table 1: Overview of the studied universities' entrepreneurship education offereings, from Aadland and Aaboen (n.d.)

Country	University	Entrepreneurship courses included in the study	Entrepreneurship programmes included in the study	Organization
Denmark	Aalborg University	4-day interdisciplinary workshop; courses as part of bachelor programme	2-year master programme	Several departments involved; collaboration; "hub" organizing activities
	Aarhus University	Summer course; courses as part of bachelor programmes		Mostly one department delivering courses to other departments
Finland	Aalto University	Two minors as part of other programmes; courses as part of other programmes		One department provides 50% of the courses; other departments offer related courses; student "hub" organizing activities
	Technical University of Tampere	Minor and courses as part of other programmes		Collaboration between three universities; "hub" organizing activities
Iceland	University of Iceland	Courses as part of other programmes	3-semester master programme	Collaboration primarily between two departments
	University of Reykjavik	3-week interdisciplinary course; minor as part of master programme		Courses primarily organized by one department
Norway	Norwegian University of Science and Technology	Courses as part of master programmes	2-year master programme	Programme and courses from one department; student "hub" organizing activities
	Arctic University	Courses as part of master programmes	2-year master programme with two tracks	Programme and courses from one department in collaboration with semi-internal lab

Sweden	Chalmers University of Technology	Courses as part of master programme	2-year master programme with four tracks	Programme and courses from one department; "hub" organizing activities
	Lund University	Courses as part of master programmes	1-year master programme	Programme from one department; collaboration with science park

6.4 Educational Approaches in Entrepreneurship Education

With the development from a business focus to the entrepreneurial individual and its mindset, the design of the learning has gone from a passive approach to more action-based education (Aadland & Aaboen, 2018; Rasmussen & Sørheim, 2006). Traditional lectures, readings and case studies (Gartner & Vesper, 1994) have been expanded to simulations (Pittaway & Cope, 2007b) and real venture creation (Lackéus & Williams Middleton, 2015; Rasmussen & Sørheim, 2006; Fayolle, A., Verzat, C. & Wapshott, R. 2016). In the field in general, numerous teaching methods are found in addition to those mentioned, such as videos and filming, games and competition, role models and guest speakers, projects, workshops, presentation, discussions and group work, study visits, business plan creation, internships, peer-learning, reflections and feedback from faculty (Aadland & Aaboen, 2018; Mwasalwiba, 2010). In the organizing of these, prior literature has separated education as "about, for or through" entrepreneurship (Hannon, 2005; Hoppe et al., 2017; Pittaway & Cope, 2007b), in which "about" is aiming at giving students basic insights in entrepreneurship. Education "for" entrepreneurship aims at giving students skills and competences needed for acting entrepreneurial, while education "through" aims at giving the students real experiences through actual entrepreneurial action. However, this classification has various definitions (e.g. Hoppe et al., 2017; Mwasalwiba, 2010), but could be compared to "passive, participative or self-driven" (Aadland & Aaboen, 2018) if the educational approaches embedded in the "about, for or through" classification were to be compared to this framework.

In the development of educational designs, the approaches are to a higher degree now aiming at reaching the self-driven class, that is, approaches where the students themselves are more self-directed in their learning (Robinson et al., 2016). This could be through simulations (Pittaway & Cope, 2007b), time-limited, student-driven business development and activities (Stone et al., 2005), or real venture creation (Lackéus & Williams Middleton, 2015; Rasmussen & Sørheim, 2006). In these cases, the students are responsible for their own learning situation to a higher extent, and need to handle entrepreneurial situations, where uncertainty and risk are central (Robinson et al., 2016), but also where the experiences are giving the students learning beyond traditional internships (Creed et al., 2002). In the latter example with internships, which is a more participatory design, the students are obtaining experiences through activities detailed through applying pre-defined tools, methods or goals, which is different from the self-directed students who might not know what the problems they are solving are (Aadland & Aaboen, 2018).

However, while the approaches are becoming more action-based and student-centred, Robinson and colleagues (2016) warned about bringing the educational approach to not only being student-centred, but also to include more traditional or passive approaches. This is a necessity in order to be able to let the students understand why the different methods or tools are introduced and how these could or could not be applied, in addition to giving the students an understanding of the development of the field of entrepreneurship and the approaches in it. This will also be central for the reflections that the students need to be able to learn through an experiential approach (Hägg & Kurczewska, 2016), which is central to the development of an entrepreneurial mind-set.

In terms of curricula and a focus on the entrepreneurial activities, the field of course differs depending on whether the education's focus is broad or narrow. Activities connected to new venture creation, such as business planning or small business management, are present in the programme or courses in applying the narrow approach to entrepreneurship, while activities connected to the entrepreneurial mind-set could be found in both the broad and narrow approach. Examples of the latter could be opportunity recognition (Baggen et al., 2018) or teamwork (Täks et al., 2016). Nonetheless, the field in general also contains business planning, new venture creation, risk and uncertainty, marketing, organization and team building, managing growth, as well as financing and marshalling resources subjects taught in entrepreneurship (Mwasalwiba, 2010).

Hence, the differences found in approaches and content in entrepreneurship education are vast, with the design depending on its objectives, students and extent. For this reason, some educations might apply complex designs involving several activities and foci, whereas others are more limited, as this fits their objectives and students. In Box 2, a presentation by the NTNU School of Entrepreneurship follows, which provides an example of how different learning approaches are included together with students' new venture creation processes.

Box 2: The NTNU School of Entrepreneurship

The NTNU School of Entrepreneurship (NSE) is a two-year, 120 ECST programme in entrepreneurship, open to all students from different disciplines with a Bachelor's degree or similar. The programme has a cohort of approximately 35 students each year, who are selected for the programme through a process in which they are evaluated based on an application letter, their grades and an interview with faculty. Over more recent years, the programme has had 30-40% females, while the students' background has been approximately 50% engineers, 35% social sciences and the rest from subjects in the sciences. The programme has its own incubator (only for the programme's students) organized by the students, where both the first- and second-year students have their offices.

Central to the NSE's education is that the students start and run their own new venture during the two-year programme. These ventures are based on different business ideas tested through a course on feasibility studies and market assessment that the students take during their first semester. The ideas often come from the students themselves, but also from industry, collaborating TTOs or research labs, or from the university's employees in some cases. In the same course, the students also travel to CERN's research laboratory in Geneva, Switzerland, where they test and verify CERN's technology potential for commercialization. This collaboration has resulted in several student teams collaborating with CERN and creating new ventures based on their technology. After the first semester, the students join in teams and select different ideas, which they later start new ventures based upon. The venturing process runs through the last three semesters, in which courses are connected to the activities in the various new ventures. Thus, the programme uses the students' experiences in their ventures as "a vessel for learning" (Lackéus &

Williams Middleton, 2015), with reflections on their activities a part of the curricula and assignments in the first two semesters, and through conversations with faculty during their last year.

The different courses, and how they are organized, are illustrated by Figure Box 2-1 below. The specialization courses are discipline-specific courses that the students choose based on their previous study background. The various courses included in the programme all hold, or together hold, a focus on being traditional, participatory and student-driven. One example is the course, "Idea search and feasibility study", which contains traditional lectures, diaries for reflection and readings, but is also participatory through the introduction and application of tools and methods, report writing and presentation, and is self-driven through the choices that the students have to make in terms of which methods to apply and problems to solve. This tripartition is reinforced later in the programme, when the students' ventures are actively used in the courses, e.g., in "Technology-based business development". The programme is also experimenting and testing out new methods to be able to further connect the students' activities in the second and third semester to theoretical frameworks in the third semester, for example through case writing on the students' own ventures.

In terms of content, the programme introduces topics that are general and necessary for all ventures, though differently applied in the different new ventures based on their nature. Examples here are intellectual property rights and financials, as these topics applies to both product- and software-based ventures. Other topics include business planning, business modelling, strategy, marketing, negotiations and teamwork central to the programme; also illustrated in Figure 1 and the programmes' courses.

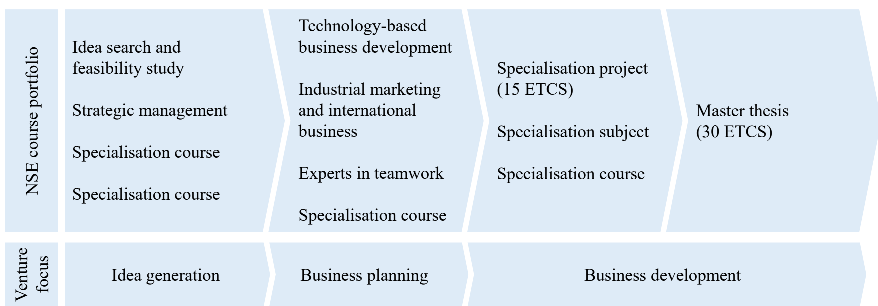


Figure Box 2-: NSE programme design with courses and business focus. All courses are 7.5 ETCS unless stated otherwise, with the specialization courses selected by the students based on their prior study background.

The programme's objective is to develop the students as entrepreneurs with skills and a mind-set such that they might become business developers. The term *business developers* is defined here as individuals who can work in private or public industry, and in small or big organizations, where the graduates further develop these businesses. However, some students continue, and are encouraged to do so, in the ventures they start during NSE. Each year, approximately 50% of the students start working full-time in their own ventures upon graduation. And while this number in each cohort is somewhat reduced one year after graduation, a recent study by Aadland and Haneberg (2018) shows that on average students participating in the programme pursue more opportunities simultaneously and work in new ventures longer, compared to those who applied for the programme, but were not enrolled when controlling for the enrolment process.

6.5 Extra- and Co-Curricular Entrepreneurship Education

As identified by Aadland and Aaboen (2018), the content and form of education are also considerably influenced by the education's context, i.e., the university´s entrepreneurial ecosystem. Some educational programmes collaborate with local industry (Stone et al., 2005; Yemini & Haddad, 2010), in which students' ventures solve problems for established companies and at the same time receive guidance and financial support. This is an indication that the education's context (i.e. the university´s contact network with firms in the region and nationally) shapes the actual content of the education offered by the specific university. This context of an entrepreneurial ecosystem at the university therefore influences not only the form of education, but also the initiatives that exist among faculty and students (Levie, 2014; Wright et al., 2017). As such, extra- and co-curricular initiatives have become more important in entrepreneurship education.

Examples of extra- and co-curricular initiatives have been mentioned in the description of the student-TTO collaboration in Lackéus and Williams Middleton (2015), or in the description of student-mentors for faculty and other students by Levie (2014). In addition, are there other initiatives like student clubs, business plan competitions, mentoring services and student incubators (Bischoff et al., 2018; Boh et al., 2016; Pittaway et al., 2011, 2015). The findings from the literature show that these initiatives are an important source for learning-by-doing, and for giving the students experiences and social learning (Pittaway et al., 2011). While the focus on this topic has been rather limited in the literature (Pittaway et al., 2011; Pittaway & Cope, 2007a), more research has emerged over later years, as this phenomenon has become more and more important in the university's ecosystem (Siegel & Wright, 2015).

However, as Wright and colleagues (2017, p. 919) write: "It is difficult to create a student entrepreneurship ecosystem from scratch or in a vacuum. Existing start-ups and entrepreneurial projects are needed." Thus, these ecosystems appear to be built through a collaboration among the university, its faculty and students, and where an initiative and need is identified among the students. The following two examples are both initiatives that were started by students, but where the first also had a close collaborator and stakeholder in local industry when it was initiated (see Box 3).

Box 3: Two examples: Spark* NTNU and Start

Spark* NTNU is an organization that delivers mentoring services for- and by students at the university. The service is free, and the mentors are employed by the university. The mentors are often students at the previously mentioned NTNU School of Entrepreneurship, who have some experience as entrepreneurs and business developers. The primary goal of the organization is to help students bring their ideas to the next level, and to give them some experience in working on their own ideas. Consequently, it is not a goal to help the students such that all ideas are becoming the students' workplace upon graduation, but rather to change the students' attitude towards entrepreneurship and to show them that their own venture is a possibility.

By 2018, Spark* NTNU guided more than 300 projects, with approximately 1,000 students having been reached through the initiative. In addition to the mentoring service, it has also arranged numerous events like "Join a start-up night" and "Thirsty Thursday". Student teams might also apply for a small grant from Spark* NTNU (up to 25,000 NOK) for travel, prototyping or equipment, so that the next level of their ideas might be reached. While the students run Spark* NTNU, it also collaborates with faculty at NTNU, and is a member of "Engage – centre of excellence in education", which is located at NTNU and Nord University.

The other example of a student-led organization is Start NTNU, which is a part of Start Norway. This nationwide organization is non-profit, and aims at promoting innovation, sustainability and entrepreneurship at higher education institutions in Norway. It is currently established at 17 higher education institutions in Norway, and hosts both local and national events. This organization also collaborates with local industry, but where Spark* NTNU focuses on developing ideas, Start NTNU could be said to be an initiator of ideas among the students. As such, these two organizations succeed each other, and have a close collaboration at NTNU.

6.6 Assessment of Entrepreneurship Education

As presented in the previous sections, the focus on entrepreneurship education increased tremendously, not only through curricular activities, but also in the universities' environment and context. However, with the increase in new collaboration opportunities and co-curricular activities, in addition to the changes in focus and approaches for entrepreneurship education, a recurring question is whether entrepreneurship education works and how well it works, which is reflected in the increase in the literature on assessment (Longva & Foss, 2018; Nabi et al., 2017). Meanwhile, as the number of studies on this topic is rising, questions could be asked as to whether the methods applied today give us the correct answers (Longva & Foss, 2018; Rideout & Gray, 2013), which calls for new methods and foci already made (Nabi et al., 2017; Roberts et al., 2014).

When the early literature on entrepreneurship education pointed at new venture creation as the preferred outcome, researchers immediately faced the problem with the potential time lag between graduation and new venture creation (Duval-Couetil, 2013). A way to handle this issue was to introduce alternative outcome measures for entrepreneurship education in the assessment, e.g., entrepreneurial intentions (Bae et al., 2014), but also to apply different measures at different time intervals (Nabi et al., 2017). Duval-Couetil (2013) found that measures in the literature could be course-specific, programme level or focused instruments, while Longva and Foss (2018) divide between cognitive, skill-based, affective, conative and behavioural measures. Hence, numerous ways have evolved in terms of assessment, but with a literature flourishing with various approaches, designs and assessment literature missing thorough descriptions of the education assessed (Nabi et al., 2017), doubt still exists on which approaches are best for entrepreneurship education. However, while many measures exist, the investigation of students' entrepreneurial intentions is much more applied than others are (Rideout & Gray, 2013).

The theory of entrepreneurial intentions builds on the theory of planned behaviour (Ajzen et al., 1991), which in short is a measure of someone's "desire to own or start a business" (Bae et al., 2014, p. 218). While this measure has been applied numerous times (e.g. Chen et al., 1998; Kolvereid & Moen, 1997; Seibert et al., 2005), it sometimes shows negative results for entrepreneurship education (Oosterbeek et al., 2010), as the measure itself could be questioned as being efficient in assessing entrepreneurship education (Bae et al., 2014). In particular, the connection between intentions and action in entrepreneurship education assessment is somewhat lacking, although with some examples that have explored this topic (e.g. Rauch & Hulsink, 2015). Nevertheless, this is still important for the stakeholders of entrepreneurship education, as in the end it is the subsequent behaviour that is of interest (Westhead et al., 2001).

Hence, the question of effect in terms of reaching the education's objective is explored with ease through measures other than actual behaviour. However, this also forces the researcher to assume that the students also learn and obtain the intended knowledge and skills when applying intentions as the outcome measure and concluding on the changes in the intention measure. The same could be said about measures investigating students' trait development or similar, but this is not without potential consequences. As shown by Aadland (2019), students' learning is not only influenced by the education itself, but also by the context and collaboration that the students have with the outside world. For instance, in a forthcoming work by Haneberg and Aadland (n.d.), they found that students creating new ventures had more complex learning processes than students without new ventures in the same education. The students without new ventures learned more from the student-community they were a part of and focused on their future careers, whereas students with new ventures focused more on their start-ups and contemporary issues in their learning process (Haneberg & Aadland, n.d.). Thus, with new types of education focusing more on creating an entrepreneurial mind-set through student-directed learning operating in the real world, the learning and outcomes from the education become more open-ended (Aadland, 2019). This student-specific perspective is difficult to account for with the assessment tools that are applied, as these often imply that the students learn the same, without taking the context into consideration, nor the learning approach that the education applies (Aadland, 2019).

However, the measures that are applied when the students are in their educational pathway are still in the majority, with the convenience of these methods likely the reason for their outnumbering compared to longitudinal research on graduates' activity, which experiences a lack of research. While a minority of entrepreneurship education graduates work in their own ventures (Dahlstrand & Berggren, 2010), few have explored how the education has an effect on the students' employability and task performance, although calls for this have been made (Pittaway & Cope, 2007a). One example that has explored this is a study by Premand and colleagues (2016), which explored self-employment rates in Tunisia after introducing students to a new type of educational design, though with mixed results. On the other hand, others have explored graduates' actions in other ways, which illustrated a positive influence from entrepreneurship education (Åstebro et al., 2012; Dahlstrand & Berggren, 2010; Lyons & Zhang, 2018).

Although the literature is increasing in terms of entrepreneurship education assessment, there is still a need for new methods, and with the importance of the context and students' role in the entrepreneurial ecosystem at the university (Siegel & Wright, 2015), more focus should be on the contextual factors in the assessment of entrepreneurship education (Aadland, 2019; Nabi et al., 2017). Moreover, with the students' learning being influenced by the context and community they are a part of (Haneberg & Aadland, n.d.), and also being dependent on the learning approaches applied in the education (Aadland, 2019), a holistic view and approach is needed when assessing entrepreneurship education. Therefore, entrepreneurship education cannot be separated with ease from its university like other courses or disciplines might; it is much more context-dependent.

6.7 Conclusion and implications

This chapter has explored some of the most prominent developments in entrepreneurship education and its impacts. While the early literature on entrepreneurship education focused on the processes of starting new ventures and had this as their primary objective, modern entrepreneurship education focuses on the individual and the development of entrepreneurial mind-sets. This is reckoned to be achieved through experiencing entrepreneurial activities, which invokes more action-oriented and student-centred learning approaches. By obtaining such a mind-set, students have the possibility to be entrepreneurial in a number of different situations, not only through new ventures, but also in established organizations, both public and private.

With this broader focus on the outcomes of entrepreneurship education, several disciplines have adopted and embedded entrepreneurship into their curricula, and as such, the organizing of entrepreneurship education at different universities has evolved into several different and new designs. Some universities offer mandatory courses, while others have hubs offering entrepreneurship education to students willing to take courses within this topic. At some universities extra- and co-curricular activities in entrepreneurship are also emerging, being implemented in the context through, e.g., mentoring services or incubators, and being central and important in the development and creation of the universities' entrepreneurial ecosystem.

Furthermore, as the students are offered more education that has a student-directed design, this gives the students more freedom and control of their learning situation. However, as argued by several, there should also be a balance between teacher-directed and student-directed education, since the latter is a source to more open-endedness in terms of learning among the students. The same is also the case where students are working in more authentic or real situations; while this gives the students a source of experience that moderates the development of their entrepreneurial mind-set, it also introduces extra uncertainty into the learning situation.

These points are also of importance in assessing the impacts of different entrepreneurship educations. As the literature on entrepreneurship education assessment increases, the context of the entrepreneurship education is still an ignored factor. In addition, the students' learning process has been shown to even vary between students within the same education, this being of importance when assuming equal learning when applying different outcome measures in different assessment studies.

Thus, entrepreneurship education and the impact assessments of entrepreneurial education activities are a complex topic, and what appears to be successful at one location and one university might not be appropriate at other locations. The contextual differences should be accounted for in assessment, but also when considering new initiatives and courses or programme development in entrepreneurship.

Bibliography

Aadland, T. (2019). *The Influence of Students' Learning in Entrepreneurship Education Assessment*. Norwegian University of Science and Technology. To be handed in August, 2019.

Aadland, T., & Aaboen, L. (2018). Systematising Higher Education: A Typology of Entrepreneurship Education. In U. Hytti, R. Blackburn & E. Lavern (Eds.), *Entrepreneurship, Innovation and Education: Frontiers in European Entrepreneurship Research*. Cheltenham, UK: Edward Elgar Publishing, pp. 103–122.

Aadland, T., & Aaboen, L (n.d.). An Entrepreneurship Education Taxonomy Based on Authenticity. *Paper in review*.

Aadland, T., & Haneberg, D. H. (2018). Career Characteristics of Entrepreneurship Education Graduates. *Presented at RENT XXXII, November 15*, Toledo, Spain, 2018.

Ajzen, I., Netemeyer, R., & Van Ryn, M. (1991). The theory of planned behavior. *Orgnizational Behavior and Human Decision Processes* 50: 179–211.

Åstebro, T., Bazzazian, N., & Braguinsky, S. (2012). Startups by recent university graduates and their faculty: Implications for university entrepreneurship policy. *Research Policy* 41(4): 663–677.

Bae, T. J., Qian, S., & Miao, C. et al. (2014). The Relationship between Entrepreneurship Education and Entrepreneurial Intentions: A Meta-Analytic Review. *Entrepreneurship Theory and Practice* 38(2): 217–254.

Baggen, Y., Kampen, J. K., & Naia, A. et al. (2018). Development and application of the opportunity identification competence assessment test (OICAT) in higher education. *Innovations in Education and Teaching International* 55(6): 735–745.

Bischoff, K., Volkmann, C. K., & Audretsch, D. B. (2018). Stakeholder collaboration in entrepreneurship education: An analysis of the entrepreneurial ecosystems of European higher educational institutions. *Journal of Technology Transfer* 43(1): 20–46.

Blenker, P., Korsgaard, S., & Neergaard, H. et al. (2011). The Questions We Care About: Paradigms and Progression in Entrepreneurship Education. *Industry and Higher Education* 25(6): 417–427.

Boh, W. F., De-Haan, U., & Strom, R. (2016). University technology transfer through entrepreneurship: Faculty and students in spinoffs. *Journal of Technology Transfer* 41(4): 661–669.

Boore, J., & Porter, S. (2011). Education for entrepreneurship in nursing. *Nurse Education Today* 31(2): 184–191.

Chen, C. C., Greene, P. G., & Crick, A. (1998). Does entrepreneurial self-efficacy distinguish entrepreneurs from managers? *Journal of Business Venturing* 13(4): 295–316.

Creed, C. J., Suuberg, E. M., & Crawford, G. P. (2002). Engineering Entrepreneurship: An Example of A Paradigm Shift in Engineering Education. *Journal of Engineering Education* 91(2): 185–195.

da Silva, G. B., Costa, H. G., & de Barros, M. D. (2015). Entrepreneurship in Engineering Education: A Literature Review. *International Journal of Engineering Education* 31(6): 1701–1710.

Dahlstrand, Å. L., & Berggren, E. (2010). Linking Innovation and Entrepreneurship in Higher Education: A Study of Swedish Schools of Entrepreneurship. In R. Oakey, A. Groen & P. van der Sijde P. et al. (Eds.), *New Technology-Based*

Firms in the New Millennium. Bradford, UK: Emerald Group Publishing Limited, pp. 35–50.
Duval-Couetil, N. (2013). Assessing the Impact of Entrepreneurship Education Programs: Challenges and Approaches. *Journal of Small Business Management* 51(3): 394–409.
Faherty, A. (2015). Developing enterprise skills through peer-assessed pitch presentations. *Education + Training* 57(3): 290–305.
Fayolle, A., Verzat, C. & Wapshott, R. (2016). In quest of legitimacy: The theoretical and methodological foundations of entrepreneurship education research. *International Small Business Journal* 34(7): 895–904.
Gartner, W. B., & Vesper, K. H. (1994). Experiments in entrepreneurship education: Successes and failures. *Journal of Business Venturing* 9(3): 179–187.
Hägg, G., & Gabrielsson, J. (2019). A systematic literature review of the evolution of pedagogy in entrepreneurial education research. *International Journal of Entrepreneurial Behaviour & Research*: Ahead-of-print.
Hägg, G., & Kurczewska, A. (2016). Connecting the dots: A discussion on key concepts in contemporary entrepreneurship education. *Education + Training* 58(7/8): 700–714.
Handscombe, R. D., Rodriguez-Falcon, E. & Patterson, E. A. (2008). Embedding enterprise in science and engineering departments. *Education + Training* 50(7): 615–625.
Haneberg, D. H., & Aadland, T. (forthcoming). Learning From Venture Creation in Higher Education. *Industry and Higher Education*.
Hannon, P. D. (2005). Philosophies of enterprise and entrepreneurship education and challenges for higher education in the UK. *The International Journal of Entrepreneurship and Innovation* 6(2): 105–114.
Hoppe, M., Westerberg, M., & Leffler, E. (2017). Educational approaches to entrepreneurship in higher education. *Education + Training* 59(7/8): 751–767.
Hynes, B. (1996). Entrepreneurship education and training – introducing entrepreneurship into non-business disciplines. *Journal of European Industrial Training* 20(8): 10–17.
Jones, C., & English, J. (2004). A contemporary approach to entrepreneurship education. *Education + Training* 46(8/9): 416–423.
Katz, J. A. (2003). The chronology and intellectual trajectory of American entrepreneurship education. *Journal of Business Venturing* 18(2): 283–300.
Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development*. New Jersey: Englewood Cliffs.
Kolvereid, L., & Moen, Ø. (1997). Entrepreneurship among business graduates: Does a major in entrepreneurship make a difference? *Journal of European Industrial Training* 21(4): 154–160.
Krueger, N. F. (2007). What lies beneath? The experiential essence of entrepreneurial thinking. *Entrepreneurship Theory and Practice* 31(1): 123–138.
Kuratko, D. F. (2005). The Emergence of Entrepreneurship Education: Development, Trends, and Challenges. *Entrepreneurship Theory and Practice* 29(5): 577–598.
Lackéus, M., & Williams Middleton, K. (2015). Venture creation programs: Bridging entrepreneurship education and technology transfer. *Education + Training* 57(1): 48–73.
Levie, J. (2014). The university is the classroom: Teaching and learning technology commercialization at a technological university. *Journal of Technology Transfer* 39(5): 793–808.

Lindberg, E., Bohman, H., & Hulten, P. et al. (2017). Enhancing students' entrepreneurial mindset: A Swedish experience. *Education + Training* 59(7/8): 768–779.
Longva, K. K., & Foss, L. (2018). Measuring impact through experimental design in entrepreneurship education: A literature review and research agenda. *Industry and Higher Education* 32(6): 358–374.
Lyons, E., & Zhang, L. (2018). Who does (not) benefit from entrepreneurship programs? *Strategic Management Journal* 39(1): 85–112.
McDonald, S., Gertsen, F., & Rosenstand, C. A. F. et al. (2018). Promoting interdisciplinarity through an intensive entrepreneurship education post-graduate workshop. *Higher Education Skills and Work-Based Learning* 8(1): 41–55.
McMullan, W. E., & Long, W. A. (1987). Entrepreneurship education in the nineties. *Journal of Business Venturing* 2(3): 261–275.
Mwasalwiba, E. S. (2010). Entrepreneurship education: A review of its objectives, teaching methods, and impact indicators. *Education + Training* 52(1): 20–47.
Nabi, G., Liñán, F., & Krueger, N. F. et al. (2017). The impact of entrepreneurship education in higher education: A systematic review and research agenda. *Academy of Management Learning & Education* 16(2): 277–299.
Neck, H. M., & Corbett, A. C. (2018). The Scholarship of Teaching and Learning Entrepreneurship. *Entrepreneurship Education and Pedagogy* 1(1): 8–41.
Neck, H. M., & Greene, P. G. (2011). Entrepreneurship Education: Known Worlds and New Frontiers. *Journal of Small Business Management* 49(1): 55–70.
O'Connor, A. (2013). A conceptual framework for entrepreneurship education policy: Meeting government and economic purposes. *Journal of Business Venturing* 28(4): 546–563.
Oosterbeek, H., van Praag, M. & Ijsselstein, A. (2010). The impact of entrepreneurship education on entrepreneurship skills and motivation. *European Economic Review* 54(3): 442–454.
Oswald Beiler, M. R. (2015). Integrating Innovation and Entrepreneurship Principles into the Civil Engineering Curriculum. *Journal of Professional Issues in Engineering Education and Practice* 141(3).
Pache, A-C., & Chowdhury, I. (2012). Social Entrepreneurs as Institutionally Embedded Entrepreneurs: Toward a New Model of Social Entrepreneurship Education. *Academy of Management Learning & Education* 11(3): 494–510.
Pittaway, L., & Cope, J. (2007a). Entrepreneurship Education: A Systematic Review of the Evidence. *International Small Business Journal* 25(5): 479–510.
Pittaway, L., & Cope, J. (2007b). Simulating entrepreneurial learning: Integrating experiential and collaborative approaches to learning. *Management Learning* 38(2): 211–233.
Pittaway, L., Rodriguez-Falcon, E., & Aiyegbayo, O. et al. (2011). The role of entrepreneurship clubs and societies in entrepreneurial learning. *International Small Business Journal* 29(1): 37–57.
Pittaway, L. A., Gazzard, J., & Shore, A. et al. (2015). Student clubs: Experiences in entrepreneurial learning. *Entrepreneurship and Regional Development* 27(3–4): 127–153.
Plaschka, G. R., & Welsch, H. P. (1990). Emerging Structures in Entrepreneurship Education: Curricular Designs and Strategies. *Entrepreneurship: Theory & Practice* 14(3): 55–71.
Politis, D. (2005). The process of entrepreneurial learning: A conceptual framework. *Entrepreneurship Theory & Practice* 29(4): 399–424.

Premand, P., Brodmann, S., & Almeida, R. et al. (2016). Entrepreneurship Education and Entry into Self-Employment Among University Graduates. *World Development* 77: 311–327.

Rasmussen, E. A., & Sørheim, R. (2006). Action-based entrepreneurship education. *Technovation* 26(2): 185–194.

Rauch, A., & Hulsink, W. (2015). Putting entrepreneurship Education where the intention to Act lies: An investigation into the impact of entrepreneurship education on entrepreneurial behavior. *Academy of Management Learning & Education* 14(2): 187–204.

Rideout, E. C., & Gray, D. O. (2013). Does entrepreneurship education really work? A review and methodological critique of the empirical literature on the effects of university-based entrepreneurship education. *Journal of Small Business Management* 51(3): 329–351.

Roberts, J., Hoy, F., & Katz, J. a. et al. (2014). The Challenges of Infusing Entrepreneurship within Non-Business Disciplines and Measuring Outcomes. *Entrepreneurship Research Journal* 4(1): 1–12.

Robinson, S., Neergaard, H., & Tanggaard, L. et al. (2016). New horizons in entrepreneurship: From teacher-led to student-centered learning. *Education + Training* 58(7/8): 661–683.

Saukkonen, J., Nukari, J., & Ballard, S. et al. (2016). Start-up entrepreneurs and university students in a co-learning mode: Learning effects of a collaborative entrepreneurial coaching programme. *Industry and Higher Education* 30(3, SI): 224–238.

Seibert, S. E., Hills, G. E., & Zhao, H. et al. (2005). The Mediating Role of Self-Efficacy in the Development of Entrepreneurial Intentions. *Journal of Applied Psychology* 90(6): 1265–1272.

Shahiwala, A. (2017). Entrepreneurship skills development through project-based activity in Bachelor of Pharmacy program. *Currents in Pharmacy Teaching and Learning* 9(4): 698–706.

Shepherd, D. (2004). Educating entrepreneurship students about emotion and learning from failure. *Academy of Management Learning & Education* 3(3): 274–287.

Siegel, D.S., & Wright, M. (2015). Academic Entrepreneurship: Time for a Rethink? *British Journal of Management* 26(4): 582–595.

Standish-Kuon, T., & Rice, M. P. (2002). Introducing engineering and science students to entrepreneurship: Models and influential factors at six American universities. *Journal of Engineering Education* 91(1): 33–39.

Stone, D., Raber, M. B., & Sorby, S. et al. (2005). The Enterprise Program at Michigan Technological University. *International Journal of Engineering Education* 21(2): 212–221.

Täks, M., Tynjälä, P., & Kukemelk, H. (2016). Engineering students' conceptions of entrepreneurial learning as part of their education. *European Journal of Engineering Education* 41(1): 53–69.

Warhuus, J. P., & Basaiawmoit, R. V. (2014). Entrepreneurship education at Nordic technical higher education institutions: Comparing and contrasting program designs and content. *The International Journal of Management Education* 12(3): 317–332.

Westhead., P., Storey, D. J., & Martin, F. (2001). Outcomes reported by students who participated in the 1994 Shell Technology Enterprise Programme. *Entrepreneurship and Regional Development* 13(2): 163–185.

Wilson, K. (2008). Chapter 5: Entrepreneurship Education in Europe. *Entrepreneurship and Higher Education*. OECD, pp. 119–138.

Wright, M., Siegel, D. S., & Mustar, P. (2017). An emerging ecosystem for student start-ups. *Journal of Technology Transfer* 42(4): 909–922.

Yemini, M., & Haddad, J. (2010). Engineer – Entrepreneur: Combining Technical Knowledge with Entrepreneurship Education — The Israeli Case Study. *International Journal of Engineering Education* 26(5): 1220–1229.

Yi, S., & Duval-Couetil, N. (2018). What Drives Engineering Students To Be Entrepreneurs? Evidence of Validity for an Entrepreneurial Motivation Scale. *Journal of Engineering Education* 107(2): 291–317.

7. Universities and innovation in the public sector

The main research question of this chapter is: How do university researchers contribute to innovation in the public sector? The "standard" answer to this question would be that researchers provide public institutions with new, research-based knowledge – knowledge that can be utilized by public sector employees and policymakers to improve or change the ways they perform their tasks, and the way they organize public sector activities and design and implement policy reforms. Evidence from scientific publications on public sector innovation shows that this form of "policy impact" is only part of the story (Windrum & Koch 2008).

The one-dimensional knowledge transfer from academia to the policymaker narrative is too simplistic and inaccurate. It is anchored in the old linear model of innovation (see Chapter 2), in which the scientists develop new knowledge and new ideas that are transferred to public institutions by various means, most often in the form of research findings, discoveries, inventions and data.

The parallel process in university-industry interactions is most often labelled "commercialization". This model sees universities as a "reservoir" of innovation potential that both industry and the public sector can tap from when needed. In this process, the universities are the suppliers and the public sector staff the customers. The scientists are the teachers, while the public employees are the students (Richardson et. al. 2016).

Following this model, the policy problem becomes a technology transfer problem, in which both policymakers and universities attempt to come up with methods that make it easier for public institutions to find the relevant "tap".

This has led, for instance, to a strong focus on public procurement, in which policymakers have tried to make it easier for public institutions to buy research from the universities and other knowledge institutions. The focus has been on the ways laws and regulations make it harder for public institutions to take innovation into consideration when buying technology and appliances. By making the regulations more flexible, policymakers hope that it will be easier for the public institutions to gain access to the relevant technology or the knowledge needed to solve the problems these institutions are facing.

There are reasons to believe that these measures *have* helped public sector innovation, but research on innovation in the public sector in particular, and on services in general, suggests that this is a too narrow and limited view of how innovation takes place in the public sector. This way of thinking causes us to ignore other very important aspects of public sector innovation processes. Public sector employees are experts in their own right, with insights into such processes that the university researchers often lack. What the public sector people need is not necessarily ready-made solutions – those being data, technologies or policy advice – but learning partners who can help them find, digest and make use of relevant knowledge, and who can help them come up with new ways of identifying and tackling challenges and opportunities ((Gulbrandsen et. al. 2016; Thune and Mina 2016).

Innovation researchers therefore increasingly talk about co-learning and co-production in service ecosystems. This type of co-learning requires that university researchers develop a different skillset, in addition to the traditional practices of high quality, reliable and verifiable science and scholarship (Schot and Steinmueller 2018).

7.1 Modes of innovation in the public sector of relevance for Universities

Not too long ago, the term public sector innovation was considered an oxymoron. The impression was that public sector institutions and employees did not innovate. Indeed, bureaucrats *should* not innovate. Following the Weberian tradition, they should provide the stability and continuity needed to serve politicians in a proper manner. As for the service providers in hospitals, schools and transport, they apparently did not innovate either, but instead adopted new technologies and methods provided by industry and research institutions.

In hindsight it is easy to see that this point of view had to be incorrect, but the fact is that the EU Commission did not fund research on services until 1996,[14] and on public sector innovation until the Fifth Framework Programme on research.[15] This did not necessarily mean that the EU Commission was not aware of the need to boost innovation in the public sector, but that such innovations were mostly seen as an end-user product of science and industrial innovation.

It was the reorientation of innovation policy towards a more systemic understanding that changed this. One good example of this reorientation is the Technology Economy Programme (TEP) (OECD, 1992) in the early 1990s (OECD, 1992). The TEP shifted the focus from the activities carried out in research institutions and industry laboratories toward the processes that took place inside and between companies. This company-centred way of looking at innovation processes naturally focused on the companies' abilities to learn and change behaviour, and in order to do so they had to interact with other actors in the so-called *innovation system*. Innovation research documented that the companies' main learning partners were not normally science institutions, but other companies, and especially suppliers and customers (Nelson, 1982; Rosenberg, 1992; Saviotti, 1991; Fagerberg, 2006).

This systemic approach to innovation gradually enlarged the area covered, first to include services in the private sector. What this research found was that a significant part of innovation patterns in services were "soft", or non-technological, even when restricted to product and process innovations. For instance, the EU SI4S project identified three emerging categories of innovation trajectories in services: service professional and professionalizing trajectories, strategic management-based trajectories and technological trajectories (Hauknes, 1998).

Among the customers of both manufacturing and service companies, the researchers also found that public institutions, and the interaction between companies and public institutions, were not that different from the ones between companies.

[14] SI4S (Services in Innovation, Innovation in Services) under the Targeted Socio-Economic Research Programme 1994–98 (Hauknes, 1998).
[15] The Publin project was part of the Programme for research, technological development and demonstration on "Improving the human research potential and the socio-economic knowledge base, 1998-2002" under the EU's 5th Framework Programme (Koch & Hauknes, 2005).

Companies would also learn from public sector customers. Moreover, studies of public sector services confirmed the idea that innovation is much more than coming up with new “things”.

7.2 Types of innovation

The EU’s Publin project identified the following types of public innovation:

- Innovations involving changes in characteristics, the design of service products and production processes – including the development, use and adaptation of relevant technologies;
- Delivery innovations – involving new or altered ways of solving tasks, delivering services or otherwise interacting with clients for the purpose of supplying specific services;
- Administrative and organizational innovations – involving new or altered ways of organizing activities within the supplier organization;
- Conceptual innovations – in the sense of introducing new missions, new worldviews, objectives, strategies and rationales; and
- System interaction innovations – new or improved ways of interacting with other organizations and knowledge bases (Halvorsen et al., 2005).

With regard to the conceptual innovations, the Publin researchers added that these were particularly important to policy learning and policy development processes. In other words: Publin and other projects like it identified an additional type of public sector innovation in addition to what was directly relevant to services, namely innovation on the policy level, including the development of new policy strategies, policy instruments and policy narratives.

All these types of innovation activities may vary in relation to the effect they have on the surrounding community and beyond. They may be incremental – a step by step improvement of existing practices – or radical or disruptive, introducing a completely new way of solving problems. Furthermore, innovations may be new to the world, to a sector or to a particular unit of the public sector. As long as people deliberately change behaviour and practices in response to challenges and opportunities, we are facing some kind of innovation (Osborne, 2013 pp. 1; Oslo Manual, 2018).

This diversity of types of innovation – in addition to the different types of challenges public sector organizations face – illustrate why a wide variety of university and college units may contribute to such innovation, be that the development of a better and more efficient health sector, the management of fisheries, the creation of a sustainable transport system, the improvement of the educational system or the expansion of the knowledge base for policy development. This means that the way universities and university employees can contribute to public sector innovation will also vary.
This kind of co-learning and collaborative innovation is part of what is often called lifelong learning, i.e. where the employees and the people they collaborate with develop new knowledge and new competences throughout their working life. Lifelong learning may give public institutions the ability to change behavior and even transform the system. University researchers may be partners in such co-learning processes, but they may also contribute through teaching. (NOU 2019:12).

7.3 Learning and co-learning

Innovation researchers are increasingly focusing on the role of learning and learning processes, reflected in terms like "co-learning", "co-production" and "co-evolution". This way of thinking has been influenced by research on both private and public services through the concept of "ecosystems", in which innovation is the end result of interactions between the various participants of that system (Wieland, 2016).
These complex and dynamic "service ecosystems" are guided by institutions (i.e. rules, norms, meanings, symbols and similar aids to collaboration) and institutional arrangements (i.e. interdependent sets of institutions). In order to change harmful practices or ensure a transformation of the system as a whole, you need to understand that it is the end result of a co-creation process that has involved a wide variety of actors, and not only scientists, engineers and politicians (Siltaloppi, 2016; Lusch, 2015).

Røste (2018) refers to Van de Ven, Garud and Hargrave and their use of the concept of co-evolution: Innovation is developed through a series of interrelated events of technical and institutional changes. This co-evolution is the result of a collective action, in which dedicated people with different backgrounds interact. This shared interest leads to further collaboration, shared concepts and common ideas about what must be done (Røste, 2018; Van de Ven, 1994). In such scenarios, it makes little sense to picture the researcher as some objective agent looking at the system from the outside. Efficient co-evolution and co-learning requires that the researcher is, in some ways, an agent *within* the system.

7.4 Barriers and drivers

Such learning processes may be hampered by social, cultural or regulatory constraints. Turning such learning into innovation and new or improved practices may also meet with various barriers. The better the researcher understands the relevant barriers and drivers to innovation in the public sector, the better he or she can adapt and present his or her knowledge in such a way that these barriers are overcome. Policy advice that pays no heed to tacit and explicit political rules and realities are much more likely to be dismissed and ignored than those that include reflection of the possible political and institutional resistance to the adaptation of relevant policies (Koch, 2003).

Researchers have identified a wide variety of barriers and drivers for innovation, the main ones being the following (de Vries, 2016; Lewis, 2017; Cinar, 2018; Torugsa, 2016; Koch, 2005; Fuglsang & Rønning 2014):

Table 7.1: Drivers and barriers of innovation and learning in the public sector

Barriers	Drivers
• complexity and size • heritage and legacy • value systems and mental maps • risk aversion, professional resistance • need for consultation • absence of resources • lack of relevant skills • restrictive regulation and management by objectives	• highly educated employees and leaders • idealism • autonomy • autonomy and opportunity • acceptance for collaboration, co-production and co-evolution • political push • media attention • policy instruments and programmes • network participation • performance targets • competition with other units/agencies • technological opportunities

As soon as we renounce the traditional knowledge-transfer idea of researchers delivering ready-made innovations or ideas to the public sector organizations for them to use, and instead look at them as experts who may help public organizations solve problems and get around barriers, it also becomes clear that different types of university and college researchers may contribute to different parts of these processes, including the skill of navigating barriers.

Among the skills university researchers can provide are:

- The ability to solve technical problems and adapt technologies to new needs.
- Insight into biology and natural ecosystems, which can be used to improve – for instance – food production and medicines, but also help public sector institutions conceptualize the possible future implications of innovations and new practices, positive as well as negative.
- An understanding of social and cultural systems and the way humans feel, think and act. Such an understanding may contribute to the development of more efficient welfare policies. This understanding may also aid in the development of more responsible and sustainable types of products, services and policies.
- Historical "memory", identifying similar processes or patterns in the past, in order to learn from them.
- The ability to map and deconstruct narratives, mental maps, tribal languages and invested interests, in order to help all agents see themselves and their learning partners in a broader perspective.
- Didactic and pedagogical skills.
- The development of new and improved concepts, methods and theories about nature and the world.

7.5 How much do public sector organizations innovate?

There have been several attempts at gathering information on public sector innovation, with the first we know of being the Nordic MEPIN project (Measuring Innovation in the

Public Sector). A pilot study was conducted among public sector organizations in Denmark, Finland, Iceland, Norway and Sweden. The study found innovation rates on a par with innovation in the business sector, and along some dimensions even higher. Although there were methodological challenges associated with this survey, it did help debunk the myth that there is no innovation in the public sector. The MEPIN project laid the foundation for several public innovation surveys in the Nordic countries (Bloch, 2011).

The Center for Offentlig Innovation (COI) collected the first dataset regarding public sector innovation in Denmark in the years 2013-2014.[16] This "Public Sector Innovation Barometer" documented that public sector institutions, like private companies, take part in a larger system for learning, collaboration and innovation. As is also the case for innovation in the private sector, research institutions are not the primary source of technology and knowledge for innovation in the public sector, but – again as in the private sector – public sector institutions do make use of science-based knowledge, indirectly, by way of employees with a university background and by use of technology and knowledge that have strong science components, and directly, by interacting directly with researchers and research institutions.

The Innovation Barometer found that knowledge institutions (*videninstitusjoner*) take part in 21% of public sector innovation activities. In comparison, employees play a key role in 86% of the innovation surveyed, politicians 69%, citizens 63%, NGOs 14% and private companies 30% (Lykkebo, 2016). The KS innovation barometer for the Norwegian municipalities produced similar results.[17]

That being said, the 21% share of knowledge institution-based innovations in the public sector should not be considered to be low. In fact it is close to the shares reported by the business sector. Much of the innovation that takes place in both companies and public institutions is of an incremental nature, in which the organizations do not need to contact universities or research institutes directly in order to solve their problems.

DIFI, the Norwegian Agency for Public Management and e-Government, has carried out similar surveys of state organizations in Norway, one for the strategic level (ministries and directorates/agencies) and one for the operative level (subordinate service providers).[18] The data provided for the strategic level (69 interviews) shows that as many as 46% collaborate with institutions for education and higher education. On the operative level (398 interviews), 18% report collaboration with such institutions.

The Innovation Barometer data imply that the higher the level the education of the employees, the more innovative that unit tends to be. A higher education background seems to facilitate university/public institution collaboration, probably due to the fact that researchers and public employees share common knowledge, analytical approaches and communication cultures.

[16] https://www.coi.dk/en/what-we-do/innovationbarometer/
[17] https://www.ks.no/fagomrader/innovasjon/innovasjonsledelse/innovasjonsbarometeret-for-kommunal-sektor/
[18] https://www.difi.no/fagomrader-og-tjenester/innovasjon/innovasjonsbarometer-staten-2018 The website gives access to several spreadsheets with data from the survey.

7.5 How do researchers at higher education institutions collaborate with the public sector?

If we look at university/public sector collaboration from the point of view of universities, we do not have directly comparable data. However, there is the 2013 survey of 4,400 faculty members *(vitenskapelige ansatte)* in Norwegian universities and colleges that also includes questions about collaboration.

Thune, Aamot and Gulbrandsen (2014) reported that university/society interaction has been fairly stable over the previous 13 years, with the level of such interaction quite similar for the different types of institutions. The limited international data presented in the report indicates that the level of academic/societal engagement in Norway (21% of those with permanent positions at Norwegian universities) is comparable with one found in the US (17%) and Germany (20%), but is lagging behind that of countries like the UK (35%) and Spain (55%). What makes Thune et al.'s 2014 survey so interesting is that it combines a wide variety of collaborative activities, and does not rely on traditional dissemination indicators only (i.e. publications, licences, spin-offs and patents).

Table 7.2: Participation in various channels for knowledge dissemination in Norwegian universities and colleges (after Thune, 2014). There is not much variation between the different types of institutions (i.e. between traditional universities, new universities, state-owned colleges and scientific colleges).

Participation in conferences for users or the public in general	54%
Published popular article	54%
Invited to talk to users/practitioners/the public	48%
Teaching employees outside the workplace	44%
Teaching for lifelong learning in one's own institution	44%
Consultancy/advisory function in the capacity of being an expert	33%
Published a contribution to public debate	33%
Provided students to companies or other institutions	22%
Board membership	21%
Sports or cultural activities in the local community	20%
Research project in collaboration with the public sector	**18%**
School projects	14%
Research projects in collaboration with industry	14%
Commissioned research	13%
Secondary position outside the sector for higher education	11%
Development and testing of new products/prototypes	10%
No collaboration	7%
Establishing new facilities in collaboration with industry, public institutions, etc.	6%
Working for a period outside academia	6%

Public exhibitions	5%
Started a company	3%
Applied for a patent	3%
Licenced research results, etc. to user	1%

The same study draws attention to different types of activities that make a difference in regard to participation in knowledge transfer:

Men are significantly more likely to be active in commercialization activities and consultancy/part-time employment outside the institution, while women are more active in the area of teaching outside the institution. Age is of little relevance, but overall the youngest (below 40) and the oldest (over 60) are less active than the ones between 40 to 60 years old. Professors are most active in terms of research collaboration and dissemination, but the least active for consultancies and part-time employment outside the institution.

Two interesting and persistent factors are found in the fact that researchers who have received external research funding, and who have been working outside the sector of higher education, are most active in all forms of externally oriented activities. This also applies to those who predominantly do applied research (Thune, 2014, p. 46).

Collaboration with the public sector and the broader society helps university and college researchers relate to society in a different way. In spite of this, the main focus in the present research policy environment seems to be on "scientific excellence", often understood in narrow academic terms (as in the number of scientific publications and/or number of citations to scientific publications). There may often be a tension between the time allotted to collaboration with public, private and civil institutions and the hours set aside for scientific production. The Norwegian University and College Time Usage Study (*Tidsbruksundersøkelsen)* actually reports a decline in the time faculty members spend on communication and collaboration with people outside the institution. The time spent on such activities varied between four and five percent in 2016, depending on what kind of position the academics have (Gunnes 2018). Solberg (2018) argues that some of the decline may be explained by the lack of incentives for contact and collaboration with the public sector and the broader society, while there are clear and strong incentives for teaching and research.

7.6 Third generation innovation policies and innovation in the public sector

If the linear model represented the first generation innovation policy and the innovation system approach to the second, the third generation innovation policy is oriented towards the co-creation and co-production of knowledge (Rip, 2004; Stilgoe, 2019; Kuhlman, 2018; Le Blanc, 2015; Schot, 2017; Koch, 2017, 2019). This notion of the third generation innovation policies has already been presented in Chapter 2. However, for the purposes of this chapter, there are certain additional elements and points to be made that most researchers, universities and policymakers should note:

- There is a reorientation of policy towards societal and global challenges, often exemplified through the UN sustainability goals (see also next chapter).

- The understanding that these challenges require more than new inventions and new ideas (given that these may cause as many problems as they solve). Given the overall objective of a sustainable future, there is often a need for a restructuring or transformation of the entire economy, and maybe even the social and political system.
- Since research and innovation may cause (unintended) problems as they solve others, responsibility and sustainability must be part of innovation processes from day one. On their side, policymakers must take sustainability and responsibility into consideration in all strategic planning, funding and follow-up activities.
- Many of the challenges are future challenges, and what researchers, organizations and policymakers do now will have consequences for future sustainability and quality of life. No one can predict the future, but researchers and policymakers may develop various scenarios of the future, and in that way identify important challenges and opportunities (Miller, 2018; Koch, 2018).
- All stakeholders are to be involved in policy development, not only those who have normally been considered experts.

This third innovation policy represents a break with the expert vs. the global way of thinking. Neither researchers nor civil servants are seen as "objective" observers standing outside the social or political system. They are part of the social and cultural system, and as such are influenced by it. They have their own interests, their own tribal affiliations and interpret the world through their specific languages or mental maps (Kuhlmann and Rip 2018).

By black boxing science, both scientists and policymakers risk alienating citizens from science and its findings. And by thinking of the scientific process as something outside society, in which scientists deliver innovation in return for money with little consideration for how these innovations may change society, we also risk harming the environment and the welfare of citizens. The recent abuse of social media by extremists and totalitarian regimes may serve as an example of such unintended consequences (Stilgoe 2019, Koch 2019, Helmus et. al. 2018).

Public sector innovation, both in regard to the development of new and improved services, as well as strategic policymaking, therefore require a broader learning arena and broader citizen involvement, according to this "third generation" way of thinking. Moreover, these processes will have to develop ideas about the future consequences of the knowledge and technology produced (Kuhlmann and Rip 2018).
This is a learning arena where different types of experts come together to discuss needs, challenges, opportunities and solutions. Researchers bring their insight into relevant research, the scientific method and general life experience; policymakers make use of their insight into policy culture, public sector incentive structures and social change; citizens bring their insight into the needs of specific social groups; artists bring their understanding of human creativity, and so on (Rip 2004, Miller 2018).

7.7 Policy implications

Although it is hard to benchmark university/society interaction across countries within different innovation and knowledge systems, the existing data does not imply that there is little collaboration between Norwegian universities and the public sector per se.

Universities have and should have a long-term responsibility for fundamental scientific, theoretical and methodological exploration that will not be directly relevant to public sector needs in the short term. This is the way it must be, and universities will always have to balance the request for more applied research and development against this responsibility and consider the division of labour within the knowledge and innovation systems. However, due to their competence base and traditions, in some areas the universities will be especially well suited to assist public sector institutions in learning and complex innovation activities.

As soon as one adopts a third generation innovation policy perspective, focusing on society's ability to meet societal challenges and contribute to the 17 UN sustainable development goals (SDGs), the main objective of innovation policy will have to be to make public institutions capable of meeting the challenges and opportunities of the future, and not necessarily the inclusion of more university research. Yet, in some areas more university research will be needed, whereas in others the universities can make their competences count for more by changing the way they interact with public sector institutions.

Recent innovation research increasingly focuses on science/society interaction as a learning arena, where the experts from universities and colleges meet experts from working life. This also applies to public sector institutions. The public sector generally innovates as does the private sector, while the educational levels in the public sector – at least in Norway – are rapidly increasing. The fact that university researchers increasingly meet university-trained public sector employees should make such collaborations easier to carry out. The public sector representatives will have a better understanding of the potential and limitations of such research, and they will most likely be better at defining needs and requirements.

In contrast, university researchers and units do not necessarily have detailed insight into the daily life of public sector institutions, their incentive structures and culture and political demands. University/public sector co-learning and co-production may become more efficient if there are made more coherent efforts at increasing the university researchers' insight into the systemic needs of the public sector.

The fact that public sector challenges and opportunities often cut across policy areas, institutions, and ministries tells us that the researchers' ability to think outside the box will also be of increasing importance, which means that universities and colleges may aim at including researchers from different disciplines when establishing teams to help public sector organizations in their work.

Some of the most important policy implications of these trends are:

1. Societal and public sector needs are often cross-cutting, bridging policy areas, technologies and disciplines. Universities, as well as the Research Council, should develop more transdisciplinary programmes and centres that bring together researchers and students, and that may develop such cross-cutting competences inside the individual universities and between such research organizations.

2. Universities, in collaboration with relevant partners, should develop new methods for strategy development to help overcome the potential intellectual and organizational lock-ins that follow from having institutional structures developed to address the challenges of the past. This kind of strategic learning should include methods for exploring different

futures (foresight), and for including a wide variety of stakeholders and citizens.

3. Universities, whether alone or in collaboration with relevant public agencies, should develop new learning arenas (programmes, centres, projects) that unite researchers with public sector experts and policymakers for addressing societal needs. NTNU and Trondheim's *Universitetskommune* may serve as one example of how this can be done.

4. It is challenging to obtain accurate measurements of the effects that university/public sector interaction will have on public sector innovation, especially when it purports the ability of the public sector to address societal challenges. The systemic interaction and spillovers are too complex, and the effects are often long term. Universities and policymakers should nevertheless develop a set of indicators and qualitative evaluation practices that enable the identification of some of these effects and pinpoint areas for improvement.

5. The universities should identify areas for life-long learning addressing public sector needs and develop more online and offline courses adapted to the needs of public sector employees. Such strategies should be coordinated with strategies for university/public sector research collaboration, and the development of other learning arenas addressing public sector needs.

Bibliography

Audretsch, D.B., Link, A.N. (2016). *Essays in Public Sector Entrepreneurship,* Springer.

Bloch, C. (2011). Measuring Public Innovation in the Nordic Countries (MEPIN), Nordic innovation.

Cinar, E., Trott, P., Simms C. (2018). A systematic review of barriers to public sector innovation process. *Public Management Review* 21(2): 264-290.

De Vries, H., Bekkers, V., & Tummers, L. (2016). Innovation in the Public Sector: A Systematic Review and Future Research Agenda. *Public Administration* Vol. 94, No. 1, 2016 (146–166).

Fagerberg, J., & Mowery, D. C. (Eds.) (2006). The Oxford Handbook of Innovation, Oxford Handbooks.

Fagerberg, J., Mowery, D. C., & Verspagen, B. (2009). *Innovation, Path Dependency, and Policy*, In J. Fagerberg & D. C. Mowery (Eds.) (2006). The Oxford Handbook of Innovation, Oxford Handbooks.

Fuglsang, L. & Rønning, R. (2014): Public Service Sector Innovation in Context, in Rønning, Enquist & Fuglsang 2014.

Gulbrandsen, M., Hopkins, M.; Thune, T.,Valentin, F. (2016): Hospitals and innovation: Introduction to the special section, *Research Policy* 45 (2016) 1493–1498.

Gunnes, H. (2018). Tidsbruksundersøkelse for universiteter og høgskoler: En kartlegging av tidsbruk blant vitenskapelig og faglig tilsatte i 2016, NIFU Arbeidsnotat 2018:2.

Halvorsen, T., Hauknes, J., Miles, I., & Røste, R. (2005). On the differences between public and private sector innovation, Publin Report No. D9, STEP.

Hauknes, J. (1998). *Services in innovation - Innovation in services,* STEP-report R-13 1998.

Helmus, T.,Bodine-Baron, E., Radin, A., Magnuson, M., Mendesohn, J., Marcellino, W., Bega, A., Winkelman, Z (2018). Russian Social Media Influence, Understanding Russian Propaganda in Eastern Europe, RAND.

Koch, P., Norgren, L., & Oksanen, J. (2003). Goodnip - Good Practices in Nordic Innovation Policies Part 1: Summary and Policy Recommendations. STEP Report 06/2003, SINTEF.

Koch, P., & Hauknes, J. (2005). On innovation in the public sector – today and beyond, Publin Report No. D20, STEP.

Koch, P. (2017). Johan Schot on Research and Innovation Policy in a Time of Change, *Forskningspolitikk* 3/2017.

Koch, P. (2018). To Think About the Future in a Changing World – An Interview with Riel Miller, *Forskningspolitikk* 2/2018.

Koch, P. (2019). Responsible Innovation in a Messy World: An Interview with Jack Stilgoe, *Forskningspolitikk* 2/2019.

Kuhlmann, S., & Rip, A. (2018). Next-Generation Innovation Policy and Grand Challenges, *Science and Public Policy,* 45(4), 2018, 448–454.

Le Blanc, D. (2015). Towards Integration at Last? The Sustainable Development Goals as a Network of Targets. *Sustainable Development,* 23(3), 176-187.

Lewis, J. M., Ricard, L. M., & Klijn, E. H. (2017). How innovation drivers, networking and leadership shape public sector innovation capacity. *International Review of Administrative Sciences* 2018, Vol. 84(2) 288–307.

Lusch, R. F., & Nambisan, S. (2015). A Service-Dominant Logic Perspective, *Quarterly* Vol. 39 No. 1, pp. 155-175/March 2015.

Lykkebo, O. B. (2016). Innovationsbarometeret. Center for offentlig innovation.

McKelvey, M., & Zaring, O. (2018). Co-delivery of social innovations: Exploring the university's role in academic engagement with society, *Industry and Innovation,* 25:6, 594-611, DOI: 10.1080/13662716.2017.1295364

Miller, R. et al. (2018). Transforming the Future Anticipation in the 21st Century, Routledge & UNESCO.

Nelson, R., & Winters, S. (1982). An Evolutionary Theory of Economic Change, Harvard University Press.

NOU 2019:12. *Lærekraftig utvikling, livslang læring for omstilling og konkurranseevne* (White paper from the Norwegian Markussen Commission). Departementenes sikkerhets- og serviceorganisasjon.

OECD (1992). Technology and the economy: The key relationships. OECD Publishing, Paris.

OECD (2018). Oslo Manual 2018. OECD Publishing, Paris.

OECD (2019). University-Industry Collaboration: New Evidence and Policy Options. OECD Publishing, Paris.

Osborne, S. P., & Brown, L. (2013). Handbook of Innovation in Public Services, Edward Elgar Publishers.

Richardson A. Audretsch D.B., Aldridge, T., Nadella, V.K. (2016). Radical and Incremental Innovation and the Role of University Scientist, in Audretsch & Link 2016.

Rip, A. (2004). A co-evolutionary approach to reflexive governance - and its ironies. In J-P Voss et al. (Eds.), Reflexive Governance for Sustainable Development, Edward Elgar Publishers.

Rosenberg, N., Landau, R., & Mowery, D. (1992). Technology and the Wealth of Nations, Stanford University Press.

Rubalcaba, L., Windrum, P., Gallouj, F., & Meglio Di, A. (2011). ServPPIN. The Contribution of Public and Private Services to European Growth and Welfare, and the Role of Public-Private Innovation Networks. Servppin Final Publishable Summary Report. European Commission 2011.

Røste, R. (2018). Innovation in Public Services, Wicked Problems and Multi-layered Solutions, BI Series of Dissertations No. 6, 2018.

Saviotti, P., & Metcalfe, S. (1991). Evolutionary Theories of Economic and Technological Change, Routledge.

Schot, J., & Steinmueller, W. E. (2018). Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy* 47(9): 1554-1567.

Schot, J., Boni, A., Ramirez, M., & Steward, F. (2018). Addressing the sustainable development goals through transformative innovation policy, TIPC Research Brief 2018-01.

Solberg, E. (2018). Innovasjon er ikke en tredje oppgave, *Forskningspolitikk* 2/2018.

Stilgjoe, J. (2019). Shared Space and Slow Science in Geoengineering Research. In Von Schomberg (Ed.), Handbook of responsible research and innovation. Edward Elgar Publishers.

Thune, T., Aamot, P-O., & Gulbrandsen, M. (2014). Forsknings, kunnskapsoverføring og eksternt samarbeid blant vitenskapelige ansatte i UH-sektoren. NIFU Rapport 23/2014.

Thune, T., Mina, A. (2016). Hospitals as innovators in the health-care system: A literature review and research agenda. *Research Policy* 45 (2016) 1545–1557.

Torugsa, N., & Arundel A. (2016). Complexity of Innovation in the public sector: A workgroup-level analysis of related factors and outcomes. *Public Management Review,* 18:3, 392-416.

Van de Ven, A. H., & Garud, R. (1994). The Co-evolution of Technical and Institutional Events in the Development of an Innovation. In J. A. C. Baum & J. V. Singh (Eds.), Evolutionary Dynamics of Organizations. Oxford University Press.

Vargo, S. L., & Lusch, R. F. (2017). Service-dominant logic 2025. *International Journal of Research in Marketing* 34 (2017) 46–67.

Wieland, H., Koskela-Huotari, K., & Vargo, S. L. (2016). Extending actor participation in value creation: An institutional view, *Journal of Strategic Marketing* Vol. 24, Nos. 3–4, 210–226.

Windrum, P., & Koch, P. (2008). Innovation in Public Sector Services. Edward Elgar Publishers.

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8. International dimension of universities contribution to innovation and societal change

How do universities contribute to innovation in their capacities as internationalized research and educational institutions? This chapter investigates this issue, focusing in particular on the main international arenas of research knowledge co-production in international networks involving universities.

8.1 University innovation activities as part of the European research and policy landscape[19]

There is no doubt that the most important organized multi-actor arena for the co-production of new knowledge in Europe, including Norway, is the EU's Framework Programmes for Research and Innovation (FP). The overall objective of FPs is to strengthen Europe's scientific and technological bases "by achieving a European research area in which researchers, scientific knowledge and technology circulate freely and encouraging it to become more competitive, including in its industry" (Treaty of European Union, Article 179 (Article 163 TEC)). Since the FP1 (1984-1988), the FPs have gradually increased in volume and complexity and evolved to encompass a range of different instruments, a considerable widening of the scope of research areas, and in this process new goals have been added. When the decision to work towards establishing the European Research Area (ERA) was made in 2000 (Lisbon European Council), it was decided to reshape the FP as an instrument contributing to this wider European ambition.

In a highly influential paper, Georghiou (2008) called for a radically new approach to European research. Georghiou asserted that Europe, first of all, needs to respond to a series of grand challenges and, secondly, that Europe must become more research friendly. Georghiou (2008) suggests that "Europe's strategic and applied research must be reoriented at a pan-European level to support the full range of policies that member states have agreed upon" (Georghiou, 2008, p. 935). Other scholars (Bonaccorsi, 2007; Dosi, Llerena, & Labini, 2006) have elaborated on the vested interests, complex dynamics and path-dependencies which favoured the status quo in European science policy, along with the need for institutional reforms. Some of these concerns were also reflected in the evaluation of the FP6 and the interim evaluation of the FP7, which also pointed to the need for a more transparent consultation with stakeholder communities and an explicit "programme logic" for a robust and effective FP design of themes and priorities. The "Lund Declaration" of 2009 was an effort by the EU to accommodate all these concerns. This line of policy thinking shaped, to a large extent, the new thematic and policy measure compositions of the FP7, and of the Horizon 2020 framework programmes. One of the most successful and important novelties in the EU's R&D policies was the establishment of the European Research Council (ERC) in 2007. The ERC budget is over €13 billion from 2014 – 2020, with its activities being an integral part of the Horizon 2020. The key policy intention with ERC was to create a new, pan-European funding mechanism for research of worldwide excellence, thus reflecting the urging from Georghiou (2008) that

[19] This section draws heavily from the analysis in Langfeldt et al. (2012).

Europe needed to become more research friendly. It is important to bear in mind that the EUs Framework Programmes, including the ERC, are the largest R&D and innovation programmes in the world.

The question now is what impact these research policies have had on universities' ability to contribute to innovation at the national and European levels?

Lepori et al. (2015) analysed patterns of participation of universities in European Framework Programmes. The author found a high concentration of participations in FP in a small group of universities with an excellent reputation. More specifically, a group of approximately 150 universities (out of 1,000 PhD awarding universities) accounted for over 70% of total participations in European projects in the year 2011. The FP participations of universities were hence more concentrated than the number of PhD students by institution or scientific publications by institution. The participation of universities that do not have doctorate programmes seems to be very limited in FPs. Finally, and probably most interestingly, the study found little evidence of significant country effects in EU FP participation. The main conclusion we can draw from this publication is that *universities of high-quality education and R&D are by far the most important organizational factor associated with high participation in FPs*. Enger (2018) and Enger and Castellacci (2016) found very similar results.

Arnold (2012) summarizes an already at that time long-existing evaluation record of FP evaluation, and of evaluations of different national participations in the FPs. This long evaluation record reveals that the FPs fund high-quality R&D, that the appraisal processes of project applications are tough, that the competition for funding is fierce, that the participating researchers include the scientific elite and that their outputs tend to be of a higher performance than those of non-participants, with the latter based on bibliometric measures, especially through citations. Probably the most relevant finding of Arnold (2012) for this report is that because "*the FP seems to attract the more excellent researchers in their fields, so it engages the more research-intensive companies within their respective branches*" (Arnold, 2015, p. 336). The primary outcomes from the FPs, which by design are pre-competitive, collaborative research programmes, are "intermediate knowledge outputs", as well as technical and market network relationships.

The discussion above encapsulated the basic characteristics of participation of universities in the FPs. In the subsequent discussion, we turn our focus of analysis to Norway, and in particular the findings in the last official and comprehensive national evaluation of the Norwegian participation in the EU's FP6 and FP7 (see Godø et al., 2009), in addition to a few other relevant studies on Norwegian participation patterns. What do these studies tell us about the participation patterns of Norwegian universities and their outcomes?

8.1.1 Key findings from the evaluations of Norwegian participation in the FPs

The first key observation to make is that the direct funding of Norwegian universities from the FPs is almost negligible. In 2017, FP funding amounted to 2.3% of total revenues of Norwegian universities.[20] However, this point disguises the fact that the

[20] Data from NIFU's Statistikkbank (see www.foustatistikkbanken.no/nifu/).

relative few and specialized teams from universities that participate in the FPs take part in very large projects, i.e., projects that receive an overall funding approximately 10 times more than the direct funding received by Norwegian participants from their EU projects. It is therefore no exaggeration to claim that, even for a small country like Norway, participation in FP projects provides access to a very large volume of research and innovation activities. In other words, Norway's researchers who participate in projects funded by Horizon 2020 have in fact direct access (through their participation in their EU projects) to approximately 20% of the overall volume of competitive activities funded by Horizon 2020, which is approximately 14 billion 2013 €. This implies that the Norwegian universities that participate in research and innovation activities funded by Horizon 2020 roughly amount to 20% of their total revenues. This quick calculation indicates only the research and innovation potential that resides in participating in the FPs for the individual researchers, the universities and for the participating member and associated states.

On the other hand, one should not neglect the fact that it is costly for the Norwegian government to participate in the FPs and, of course, the Norwegian contribution to the FPs is funds that could have been redirected directly back to the national research system, including the universities. Hence, the key question is whether the Norwegian research system in general, and Norwegian universities in particular, are in a position to exploit the research opportunities they have direct access to through their participation in the FPs or not.

The first relevant question to ask in this respect is whether the thematic priorities of the previous FPs and of Horizon 2020 correspond to the broader thematic priorities of the Norwegian research system. All previous evaluations found that there is a good match between Framework Programme priorities and Norwegian research priorities, so logically this is a good reason to believe that there should be many synergies between nationally funded research projects and EU funded projects where Norwegian researchers participate. Horizon 2020 also seems to have a thematic overlap with most of the large-scale national research programmes.

In addition to that, Godø et al. 2009 reported that 72% of project applicants for R&D funding in FP7 claimed that their project applications were an integrated part of their organization's internationalization strategy, again indicating synergy and coherence between FP research and participating organizations' research and research strategies. When comparing their FP projects and other national research projects, a large part of the FP6 participants reported that there are no significant differences in quality, results, strategic importance, etc. compared with nationally funded R&D-projects, with the exception that the EU projects were often more multidisciplinary.

Nonetheless, the evaluation failed to find synergies between the matching national and FP priorities *at the project level*. The evaluation data indicated limited coordination with national priorities and funding. The larger parts of FP6 participations, as well as FP7 applications, were not closely related to nationally funded research projects, and very few of the EU projects are extensions of nationally funded projects.[21] In sum, even if a large

[21] For example, 69% of the FP6 projects were not an extension/follow-up of another R&D project; 17% are extensions of previous EU projects, whereas only 6% are extensions of nationally financed projects. Moreover, less than half of the FP6 projects, and less than half of the FP7 applications, were closely linked to research for which the Norwegian participant obtained Norwegian public funding. In other words, a large part of the FP research is not related to nationally financed research. Finally, 62% of FP7 applicants believed that there was a need for better coordination between Framework Programme activities and relevant national R&D and innovation support schemes and programmes at the project level (see Godø et al., 2010; Langfeldt et al., 2012).

majority report that their FP project was an integrated part of their organization's internationalization strategy, the financial synergies between Norwegian and EU research seem limited. It is important to note, that on this point there were no significant differences between the four institutional groups of participants, i.e., participants from universities, participants from the Norwegian research sector, participants from Norwegian companies and participants from the public and civic sectors.

Obviously, one has to take into account that these findings are almost 10 years old. Nevertheless, there are also indications that today there seems to be two distinct and parallel funding trajectories after 25 years of full Norwegian participation in the FPs: Research that follows the national funding path and research projects that take the European route. In most research areas, crossing from the national to the European is less likely than staying on the European path once having entered into this.

Piro, Scordato and Aksnes (2016) is a relatively recent and comprehensive analysis of the Norwegian participation in FPs. This study focuses on project consortia and their importance for success, participation and cooperation in EU framework programmes. The study does that by juxtaposing consortia information in application and funded project data in the EU's ECORDA data.[22] In addition to ECORDA data, the study included three university characteristics: a) Number of publications in the Web of Science; b) Field-normalized citation index; c) Rank position in the Shanghai ranking. The main finding of the study is that in large parts of these FPs, joining and composing the right consortium is considered a key factor for success. Consortia characteristics are highly associated with success rates in both FP7 and Horizon 2020, across all FP sub-programmes.

Furthermore, the university partners in the funded projects are generally larger, more cited and higher ranked in the Shanghai ranking system compared to university partners in the rejected applications. The research institutions that have been most successful have two things in common: they score high on the university performance indicators mentioned above, and they successfully engage in consortia in which the partners generally also score high on the same indicators. These findings seem to suggest that consortia with high- performing universities tend to write better proposals than other consortia, and they tend to have a stronger consortia CV. The main policy implications from this study for Norway is that an efficient strategy to enhance Norway's return rate – and success rates - in EU FPs is to target and support the established players, i.e., those institutions being close to the centre of the European research network. Piro, Scordato and Aksnes (2016) conclude that, "The analysis in this report clearly underpins the need to concentrate the focus at those institutions that already have experience with proposal writing and project participation."

In 2017, Technopolis, a consultancy group, conducted a large study, commissioned by the Research Council of Norway, on the possibilities to increase Norwegian participation in Horizon 2020, but also in relation to other European Research Areas (ERA). One of the key observations in this study was that Norwegian universities (and hospital trusts) have significantly higher basic allowance funding relative to their

[22] The European COmmon Research DAta Warehouse database (eCORDA) is a database provided by the EU services, and contains detailed information on all applicants, participants and projects funded by FPs.

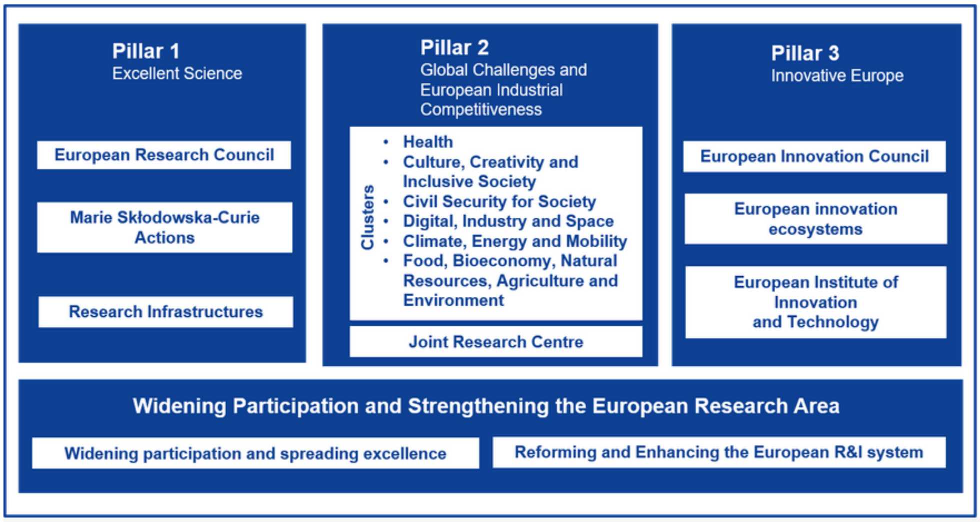
counterparts in Austria, Denmark, Finland, the Netherlands and Sweden. As several interviewees reported, the report also claims that ample national public funding (base and competitive funding together) is a strong disincentive to FP participation for HEI researchers. The study found that this is true regardless of the thematic areas of research. Technopolis (2017) confirms findings from past Norwegian FP evaluations which indicate that over time Norwegian stakeholders, including in universities, have become skilled FP participants capable of achieving high success rates. On the other hand, the study also found that a large share of Norwegian applicants appears to be part of consortia of low quality, or part of wrong networks, since their success rates as partners are very low or zero. Many of these are from Norwegian universities and yet the worrying finding is that many of these seem unaware that their international networks are often not good enough.

The overall evidence from the studies we referred to above, but also from a number of other sources, including the Research Council of Norway, suggest that there are comparatively few but highly competitive research groups in Norwegian universities that have a vast experience with EU research projects and good networks. In addition, these groups are certainly able to attract national funding, even if their nationally-funded research projects are not directly related with the research topics of their EU projects. We know very little about how these research groups connect, combine and balance these two sources of funding, if there are tensions between them, if there are synergies between their European and national networks, if they are able to exploit these opportunities, etc.

In contrast, there are a large number of research groups in all Norwegian universities that are not well-connected with high-performing research teams at the European level. These seem to primarily engage with national research funding. This is not necessarily a negative feature since many of these research groups also conduct research of a very high quality. Yet, the danger with a national-narrow research strategy is *compliance*, that is, that the predominantly nationally-, or regionally-oriented researchers, have less possibilities to connect to international research agendas, insofar as helping them to better recognize and seize research opportunities emerging outside the Norwegian research system boundaries (Godø et al., 2009). In Chapter 2, we established the fact that such research opportunities on a global/international scale tend to influence the direction of Norwegian research policy agendas, with a certain time lag.

This discussion becomes even more important and relevant for universities' *international innovation strategies*, since the next European Framework Programme, Horizon Europe, seems to explicitly target innovation in Europe with, among other activities, the creation of the European Innovation Council, under Pillar 3 (Innovative Europe). Pillar 3 will also include the European Innovation Ecosystems programme (see Figure 8.1 below), in which universities will almost certainly play a considerable role:

Figure 8.1: Preliminary structure of Horizon Europe



Source: https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en

8.2 The case of cross-border Public-Private Innovation Partnerships

There is now a sufficiently large amount of literature (European Commission, 2018; Frølund et al., 2019; Koschatzky & Stahlecker, 2016; Kuhlmann & Rip, 2018) to assert that public-private partnerships (PPPs) within innovation and R&D are gaining ground as an effective approach to fostering long-term international university-industry collaboration with a focus on designated priority areas. Still, there are a few cases of international (meaning cross-border) PPPs.

The prime examples of international PPPs are the European Innovation Partnerships (EIP), such as the European Active and Assisted Living Programme (AAL), the EIP-Water, the EIP on Agricultural Productivity & Sustainability (Agri), the EIP on Raw Materials and the EIP on Smart Cities and Communities (SCC).

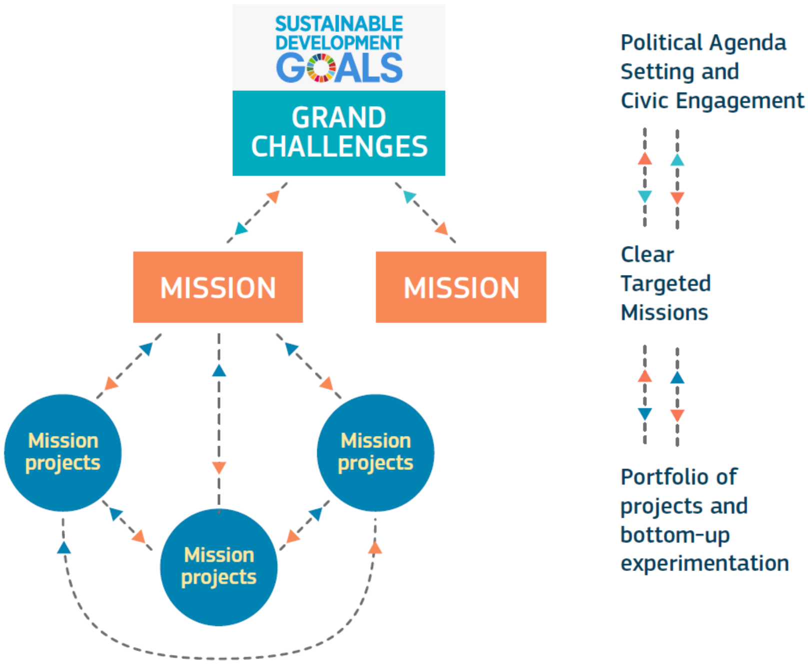
Many PPP programmes tend to operate with large budgets, but do so by concentrating resources in a limited number of centres over a relatively long period of time that cater to a larger group of beneficiaries. The analysis in Chapter 4 of this report is therefore relevant here. It suffices to mention that a growing volume of research and innovation activities is expected to be carried out within the context of international PPPs and EIPs. This adds a complexity layer to academia-industry partnerships, a complexity that HEI researchers also have to deal with in the future.

8.3 The case of global mission-oriented R&D initiatives

The transition from the United Nations Millennium Development Goals (MDGs) to the agenda 2030's Sustainable Development Goals (SDGs) altered the prospect of economic and societal development – it is now a universal/global challenge, not only an issue for developing countries alone. The MDGs have already had a considerable impact on national R&D and innovation agendas and they are bound to have profound effects on the research and educational agendas of the universities.

Mazzucato (2018) presents an analysis of possible policy approaches to mission-oriented R&D and innovation in the European Union. In doing that, her analytical starting point is the SDGs, as Figure 8.2 below illustrates. One of the important messages conveyed in this figure, is that SDGs seem to now be the natural outlet for modern research policy thinking, which will even be a more conspicuous trend in the immediate future:

Figure 8.2: From Challenges to Missions; Source: Mazzucato (2018, p. 11)



Another by-product of the same trend is also a transition in aid-financing, in which there is increasing support for multilateral financing mechanisms instead of supporting country-targeted programmes. This suggests a stronger role for STI and international cooperation in developing and coordinating national aid programmes with the ambition to more effectively contribute to specific SDG solutions. These transitions also make the traditional divide between R&D for development and R&D for national purposes increasingly more blurred. National STI policies have more of an international role to play than ever, and there are clear tendencies and attempts for improved cooperation, coordination and mechanisms for joint financing at a global level (Remøe, 2019). Such global collaboration includes research data and outputs, research evidence, knowledge, digital tools and technologies relevant for achieving the SDGs.

The challenge at hand is what it is needed to put universities in a better position to respond to these novel global trends and initiatives. This concerns modalities of funding, incentives for individual universities, institutional mechanisms for cooperation, frameworks for partnerships, etc. Very few universities seem to have the organizational knowledge capacities to address these opportunities.

8.4 Internationalization of academic entrepreneurship

There are few studies addressing the question of how *internationalization* in universities impacts academic entrepreneurship and in particular, student-based entrepreneurship.

Minola et al. (2016) is an exception. This study employs a multilevel analysis with data from 25,855 students enrolled in 130 European universities and analyses the effect of university internationalization on students' progressive engagement in entrepreneurship, as well as along the core entrepreneurial university missions (teaching, research and socio-economic contribution).

The study found that the internationalization strategy had a positive direct effect on the European students' *level of engagement in entrepreneurship*. In this regard, this study provides evidence about the effect of internationalization on European universities potential to contribute to entrepreneurship and proposes alternative measures or proxies to explore the European entrepreneurial universities' outcomes that could be replicated in other environments.

Having said that, it is important to remind the reader, as pointed out in Chapter 6, that the field of measuring impact on/and of entrepreneurship education activities is a very difficult area of research. The point of this paragraph is only to observe that this is a question that has not received adequate attention in the research literature. The scant evidence we find seems to confirm that internationalization in universities correlates with students´ increased level of engagement in entrepreneurship. There is a need for a lot more research in order to understand the interactions between internationalization and academic entrepreneurship in general.

8.5 Policy implications

Enders (2004) claims that universities and their organizational frameworks are challenged in two distinct ways: a) the European-wide policy focus on university effects/impacts and less focus on inputs (funding and human resources); and b) the concern with macro-level policymaking and meso-level organizational adaptation, neglecting to some extent the effects in the actual practices and performances of academic work at the level of individual researchers and their groups.

These are certainly tensions that have not only been mitigated, but if anything, have probably been exacerbated over the past 10 years. One of the primary reasons for that is the demand for even greater coordination, even more global division of labour in R&D and innovation profiles and a greater alignment of academic organizational strategies in knowledge societies on the one hand, and century-long practices of academic autonomy and independence in research and education on the other.

In other words, we need to devise and develop adequate organizational structures to ensure that *more science for missions* does not undermine *the mission of science*. Key questions in this respect are:

- What are the main implications of mission-oriented policies on universities' ability to conduct research, e.g., in terms of articulation of societal needs and interdisciplinary approaches?

- Does the inclusion of science into missions jeopardize its freedom, exploratory power and long-term horizon?
- How to balance – and if possible and relevantly connect – non-oriented and oriented research?
- What have been successful modes of articulation of science into missions and how can science policy support "mission-oriented science"?
- Lastly, how can Norwegian universities exploit their competitive advantages (and reduce the adverse effects of possible disadvantages) considering the new European Framework Programme for Research and Innovation, Horizon Europe, and its obvious redirection towards more mission research and more funding of innovation activities, including innovation ecosystems.

Bibliography

Arnold, E. (2012). Understanding long-term impacts of R&D funding: The EU framework programme. *Research Evaluation* 21(5): 332-343.

Audretsch, D. B., & Keilbach, M. (2008). Resolving the knowledge paradox: Knowledge-spillover entrepreneurship and economic growth. *Research Policy, 37*, 1697-1705.

Bonaccorsi, A. (2007). "Explaining the poor performance of European science: Institutions versus policies. *Science and Public Policy, 34*(4), 303-316.

Breschi, S., & Cusmano, L. (2004). Unveiling the texture of a European Research Area: Emergence of oligarchic networks under EU Framework Programmes. International *Journal of Technology Management*, 27(8), 747–772.

Dobrinsky, R. (2019). *European Innovation Partnerships: How Successful Have They Been in Promoting Innovation in the EU*? The Vienna Institute for International Economic Studies – Research Report 438 – January 2019.

Dosi, G., Llerena, P., & Labini, M. S. (2006). The relationships between science, technologies and their industrial exploitation: An illustration through the myths and realities of the so-called "European Paradox". *Research Policy*, *35*, 1450-1465.

Enders, J. (2004). Higher education, internationalisation, and the nation-state: Recent developments and challenges to governance theory. *Higher education*, vol. 47, no. 3, pp. 361-382. https://doi.org/10.1023/B:HIGH.0000016461.98676.30

Enger, S. G. (2018). Closed clubs: Network centrality and participation in Horizon 2020. Science and Public Policy 45(6): 884-896

Enger, S. G., & Castellacci, F. (2016). Who gets Horizon 2020 research grants? Propensity to apply and probability to succeed in a two-step analysis. *Scientometrics* 109(3): 1611-1638

European Commission (2018). *Mission-oriented research and innovation: Inventory and characterisation of initiatives*. Final Report, European Commission, Directorate General for Research and Innovation, Brussels.

Frølund, L., Murray, F., & Riedel, M. (2018). Developing successful strategic partnerships with universities. *MIT Sloan Management Review*, Winter Issue, pp. 71-79.

Georghiou, L. (2008). Europe's research system must change. [Commentary]. *Nature, 452*(April 2008), 935-936.

Godø, H., Langfeldt, L., & Kaloudis, A. (2009). In Need of a Better Framework for Success - An evaluation of the Norwegian participation in the EU 6th Framework Programme (2003-2006) and the first part of the EU 7th Framework Programme. Oslo: NIFU STEP.

Gornitzka, Å., & Langfeldt, L. (2008). The internationalisation of national knowledge policies. Understanding the "New" Internationalisation of Research and Higher Education in Norway. Dordrecht: Springer.

Koschatzky, K., & Stahlecker, T. (2016). Public-private partnerships in research and innovation: Trends and international perspectives, Stuttgart: Fraunhofer Verlag.

Kuhlmann, S., & Rip, A. (2018). Next-generation innovation policy and grand challenges. *Science and Public Policy*, 45(4), 448-454.

Langfeldt, L., Godø, H., Gornitzka, Å., & Kaloudis, A. (2012). Integration modes in EU research: Centrifugality versus coordination of national research policies. *Science and Public Policy* 39(1): 88-98.

Lepori, B., Veglio, V., Heller-Schuh, B., Scherngell, T., & Barber, M. (2015). Participations to European Framework Programmes of higher education institutions and their association with organizational characteristics. *Scientometrics*. 105(3): 2149-2178.

Mazzucato, M. (2018). Mission-Oriented Research & Innovation in the European Union: A problem-solving approach to fuel innovation-led growth. European Commission, Directorate-General for Research and Innovation.

Minola, T., Domina, D., & Meoli, M. (2016). Students climbing the entrepreneurial ladder: Does university internationalization pay off? *Small Business Economics*. doi:10.1007/s11187-016-9758-1.

Piro, F. N., Scordato, L., & Aksnes, D. W. (2016). Choosing the right partners: Norwegian participation in European Framework Programmes. NIFU-report 2016-41.

Remøe, S-O. (2019). Oslo Workshop on International Collaboration in Science, Technology and Innovation for Global Public Goods: The Chair's statement. Statement from the OECD workshop on Global Public Goods in Oslo, May 2019.

Technopolis (2017). Norwegian participation in Horizon 2020 in health, ICT and industry: A study on the potential for increased participation. Technopolis group.

Technopolis (2019). Raising the Ambition Level in Norwegian Innovation Policy. Technopolis report.https://www.forskningsradet.no/contentassets/9adfcaff0c4a48538c208024abd12b99/technopolis-naringsrettede-virkemidler.pdf.

9. Policy implications

In the previous chapters, we identified the main trends and findings in the literature dealing with the main research question of this report, namely *"How do modern universities contribute to the various forms of innovation and entrepreneurship?"*

The primary objective of this chapter is to draw some broad implications on the exclusive basis of the work carried out in this state of the art exercise. It is on this basis that we are now proceeding to a discussion on the policy implications of the identified problems and challenges universities face in their efforts to contribute to more *responsible innovation in the Norwegian and global economy and society*.

Methodologically speaking, our discussion below is guided by a straightforward approach: First, we formulate the challenge; for each challenge, we then provide some broad ideas about possible roads of action to tackle them.

9.1 Policy implications of international trends involving higher education institutions in Norway

The key chapters dealing with the issues of trends and internationalization are Chapters 2 and Chapter 8. Here, we focus on the following four challenges linked to these chapters:

1. The need to help individual researchers and research teams deal and engage with the increasing complexities of modern research-based innovation processes:

Modern R&D and innovation activities are increasingly more dependent on innovation and entrepreneurial networks, clusters and ecosystems. These are becoming more interdisciplinary, and are spanning across many organizational, institutional and cultural boundaries. In other words, the nature of modern university-based research and innovation processes is becoming more *complex* and *more demanding for individual academic research groups* than in the past. It is therefore important that universities develop *interaction arenas* that empower individual faculty members and their research teams to:

a) Better understand and engage with developments in the broader innovation policy landscape, regionally, nationally and internationally and, hence, be better prepared to meet opportunities and challenges as early and as adequately as possible.
b) Help develop future directions of their own research when connected to the funding opportunities available at the regional, national, EU and global levels. The more international the funding sources, the larger the complexity to succeed in project acquisition processes.
c) Facilitate researchers with the creation and maintenance of better and broader inter-disciplinary networks in multiple innovation and entrepreneurial ecosystems.

2. Keep a focus on improving the research quality in Norwegian universities per se, and also as a means to increase universities' possibilities to participate in large global research initiatives and in the EU's future Framework Programmes.

Evidence from Chapters 2 and 8 leaves little doubt: The single most important success factor for participating in the EU's Framework Programmes and for engaging with competitive international consortia is *research excellence.* This also means that persistent and robust participation in the EU's Framework Programmes, especially by the ERC, increases both the reputation of the research teams involved and of their universities. Thus, Norwegian policies must keep a focus on promoting scientific excellence in all academic fields with its various policy instruments targeting excellence. Universities could explore developing new actions with the objective to help their research groups, particularly those with a low exposure to international research collaboration, to gradually increase their international outreach and to connect to more competitive international research groups.

3. *Better exploit the synergies emerging from participation in the FPs and participation in national R&D funding schemes.*

   In Chapter 8, we presented evidence from previous evaluation records indicating that there are few synergies between participation in EU projects and national R&D programmes, and vice versa. It is not known whether this problem has worsened or improved with the advent of the Horizon 2020. The international collaboration networks and the volume of EU projects represent considerable research and innovation opportunities for the Norwegian universities. The question is what universities can do to better:

a) Seize and further exploit the opportunities that reside in nationally-funded projects as a stepping stone for new international research collaboration activities; and
b) Exploit innovation opportunities emerging in EU (or other international) projects regionally and nationally.

4. *Universities ought to seek a better understanding of the knowledge dynamics and knowledge interactions occurring between the different types of R&D activities their researchers participate in (at the project level).*

It is not only the knowledge interactions between the international and national research activities that it is important to understand. In general, we know little about how participation in activities funded by different national schemes connects to internally funded research activities, and about the dynamic interdependencies emerging between them. After all, all modern research is funded and organized as a complex web of many different research projects (large or small), conducted by one or many research groups (or occasionally by individual researchers). And yet we know little about the knowledge dynamics at this micro level. It is at that level that the funding of research and innovation activities takes place, as it is in the combination of various R&D and innovation projects that knowledge ecosystems emerge and evolve. A more detailed knowledge of these issues could generate tremendous positive outcomes for those universities that better understand the complex interdependencies between the various research and innovation activities they are involved in; thus, they can probably design smarter and more effective policy actions for their academic employees and their institutions.

5. Prepare for the new EU Framework Programme and European funding of Innovation

As mentioned in Chapter 2, from 2021 the EU's new Framework Programme for R&D and Innovation, Horizon Europe, will continue to focus on excellence in research (ERC) and on societal challenges as drivers for research and innovation. In addition, it is provisioned to adopt a new policy approach to innovation by organizing the most current innovation tools under the umbrella of a new institutional policy agency, the EIC (European Innovation Council). The EIC will include a large part of the programmes directed towards the EU's commitment to enabling technology, as well as scaling and commercialization from SMBs with global potential. The EU aims to seriously take up the competition with the US and China by investing in technology and in businesses with growth potential. This is an institutional change of potential considerable importance for many Norwegian universities, especially NTNU.

9.2 Policy Implications for university-industry collaboration channels

Related to university innovation channels and to university-industry collaboration, the following policy implications can be drawn from our literature review:

1. *The importance of the university-industry channels are found to differ across science fields and industry sectors* (Cohen et al., 2002; Bekkers & Bodas Freitas, 2008; De Fuentes & Dutrénit, 2012).

This indicates that "one size doesn't fit all", i.e., policies to induce specific channels should be carefully tailored to correspond to the specific needs of industry and relevant university actors.

2. *The literature emphasizes the role of the geographical proximity and the role of key individuals in developing university -industry collaborations*.

The implications of this point are:
- Since most collaborations occur within close *geographical proximity*, as well as being facilitated by social proximity, it is important to have university activities co-located in the *vicinity of industrial areas*, and vice versa (industry activities in the vicinity of university campus).
- The importance of key individuals (and their knowledge bases and absorptive capacity) in the collaboration process for innovation (Haas, 2015; Santoro & Chakrabarti, 1999) illustrates the importance of having individuals with a high degree of cognitive proximity and mutual understanding regarding university-industry interaction, both at the universities and the industry.

3. *The contributions of social sciences and humanities in university-industry interactions are poorly studied and insufficiently understood.*

   The few studies that exist indicate a potential for contributing to innovation. This calls for a sharper focus on more *multidisciplinary research* collaboration, including these fields, and for policymakers who should provide incentives for more frequent social scientist participation in university-industry interactions.

4. *The actual collaborative dynamics and processes that reveal how successful outcomes are developed are poorly explored in the literature (Perkmann & Walsh, 2007; Thune & Gulbrandsen, 2014; Boardman & Bozeman, 2015).*

   It is challenging for firms, universities, scholars and policymakers in UICs to assess and evaluate the impact of these collaborations (Thune, 2011; Perkmann et al., 2011). This is especially due to the uncertain nature of basic research, which makes it difficult to set clear objectives and evaluate outcomes that may come years after the UICs have ended (Perkmann et al., 2011). Moreover, firms' motive for collaborating with universities are often based on indirect and generic benefits, such as accessing students and academics, getting insights into the latest blue-sky research and developing their own, or researcher's knowledge bases (Lauvås, 2017). Firms are therefore found to be less concerned about making a quantitative case for participation (Perkmann & Walsh, 2007; Perkmann et al., 2011; Broström, 2012).

5. *There is a relation between more long-term research partnerships (e.g. research centres) and short-term research services.*

   For example, research partnerships in research centres often lead to research services being conducted "outside" the realms of the research centre (Lauvås, 2017; Iglebæk et al., 2018). This implies that proper assessments of the impact of (innovation) research centres need to pay attention to such dynamic effects and interdependencies between short-term and long-term university-industry interactions and their effects.

6. *Most research on UIC has been conducted in science-based industries such as pharmaceuticals and biotechnology (Lundvall, 2007; Broström, 2012). Many of the results from this literature must be nuanced and adjusted regarding the firm's size, characteristics and industrial affiliation, along with the importance of different dimensions of proximity.*

   Geographical proximity towards universities is important for the establishment of UICs for both small- and engineering based-firms (Slavtchev, 2013; Dornbusch & Neuhausler, 2015; Steinmo & Rasmussen, 2016). Hence, in an effort to increase UIC, collaborations with local universities can be an important starting point for these types of firms (Steinmo & Rasmussen, 2016; Fitjar & Gjelsvik, 2018), particularly since former collaboration is one of the key factors for explaining successful UICs (Bishop et al., 2011; Bruneel et al., 2010; Núñez-Sánchez et al., 2012).

7. *Universities should engage in more knowledge co-creation with industry in order to increase firms´ absorptive capacities.*

   Firm involvement and commitment in UICs are found to be important in building the absorptive capacity of firms (Santoro & Chakrabarti, 2002; Knudsen et al., 2017; Fontana et al., 2006). This is also indicated in a recent report by the OECD (2019), which recommends focusing on knowledge co-creation between universities and industry, rather than a knowledge-transfer approach. While the SFI evaluation discusses the alternative of having only industrial cash contributions and no in-kind (Damvad, 2018), the literature provided in Chapter 4 points towards having more, and not less, interaction between university and industry partners to harness the potential of UICs.

9.3 Policy implications for academic entrepreneurship

1. Commercialization, in the form of academic spin-offs (ASO), can occur through qualitatively different outcomes. Therefore, focusing only on simple or singular performance outcomes will likely lead to wrong conclusions.

While a firm might appear to be unsuccessful in one facet of performance (e.g. profits), it might simultaneously be highly successful in another (e.g. firm value). For example, trade sales of not profitable ASOs with very high valuations do occur, and more generally, trade sales seem to be an important mechanism to access the necessary resources to successfully scale-up commercialization processes. Assuming the survival of an independent ASO-firm as a precondition for success is thus misguided.

2. Skewed distributions and the extreme impact of outliers appear to be the norm in academic spin-offs. This implies that a small number of academic entrepreneurship endeavours account for the vast share of the economic results from these endeavours.

This finding implies that efforts to simply increase the number of academic spin-offs or commercialization projects are often a misplaced approach. There is a need for far more sophisticated approaches promoting and fostering promising academic spin-offs without attempting to “pick the winners”. The literature analysis in Chapter 5 clearly shows that the realization of economic impacts often takes many years to occur. It is therefore not easy to identify the “golden eggs” early in the establishment phase of the new firms. This tension between the few outliers and long time-spans for the realization of economic impacts seems to be a general feature of all science commercialization, including patenting and licencing. The point is that university TTOs should be more selective as to which firm ideas they chose to invest in, and when invested in these firms universities need to provide different types of support for a long period of time of the firm’s lifetime.

3. Trade sales often have unfavourable connotations in policy circles because of the fear that technologies and firms partly financed by governmental resources and tax money will be “sold of the country”. This fear is not validated in the literature.

The analysis is Chapter 5 shows that although acquisitions by large foreign companies do occur, the majority of buyers in the Norwegian ASO portfolio were domestic (i.e. Norwegian) firms. And many, if not most, of the ASOs acquired by foreign companies remained domestically, and even increased the scope of their business activities locally. Successful trade sales also provide high returns for entrepreneurs and venture capital (VC) investors - returns that can be re-invested into new ventures. For these reasons, policymakers should keep an open mind with respect to trade sales. More specifically, policymakers should facilitate for large foreign industry incumbents to interact with domestic PROs for the mutual benefit of both parties.

4. The time needed for the commercialization of research is very long and development and growth can be discontinuous and erratic.

The timing of evaluation matters a great deal as the status and prospects of ASOs can be dramatically changed over short periods. For example, in the days preparing this chapter the portfolio company Ultimovacs went public on the Oslo Stock Exchange with a valuation of over 500 million NOK. These findings are fully compatible with phenomena characterized by a high uncertainty and skewed outcomes such as ASOs demonstrably are.

9.4 Policy implications for Entrepreneurship Education

1. Modern entrepreneurship education focuses on the individual (student) and on the development of entrepreneurial mind-sets.

This often implies a real experiencing of entrepreneurial activities during the entrepreneurship education, which invokes more action-oriented and student-centred learning approaches. By cultivating entrepreneurial mind-sets, students have the possibility to be entrepreneurial in a number of different situations, not only through new ventures, but also in established organizations, both public and private.

2. The role of students in university entrepreneurship activities is increasingly important. There is a need to more systematically develop the conditions for student-based entrepreneurship in the overall university entrepreneurial ecosystem.

Student-based entrepreneurship activities are often linked to entrepreneurship education courses and programmes. These activities are occasionally continued during or after the study programme period as full-fledged entrepreneurial initiatives, frequently connected to mentoring services or university-centered incubators, and as such, are central drivers for the development of *university entrepreneurial ecosystems*.

3. With the new focus on the entrepreneurial mind-set and broader outcomes of entrepreneurship education, several disciplines have adopted and embedded entrepreneurship into their curricula, and as such, the organizing of entrepreneurship education at different universities has evolved into a variety of new designs.

For example, some universities offer mandatory courses, while others have hubs offering entrepreneurship education to those students willing to take courses within this topic.

4. A student-directed entrepreneurial education design provides the students with more freedom and control of-, as well as more responsibility, for their learning situation.

However, having said that the literature suggests that there must be a balance between teacher-directed and student-directed education, since the latter is a source of more open-endedness in terms of learning among the students. The same is also the case where students are working in more authentic or real situations – real entrepreneurship situations give the students invaluable experience and lead to the development of their entrepreneurial mind-set, but it also introduces extra uncertainty into the learning situation.

9.5 Policy implications for University-Public sector interactions

Related to the universities involvement in public sector innovation processes, the literature review guides us towards the following issues:

1. The challenge of the transdisciplinary nature of innovations in the public sector.

The needs of civic and public sectors are often cross-cutting, bridging policy areas, technologies and scientific disciplines. This is also often the case for the knowledge needs in the business sector. Yet, there is a much larger number of funding schemes to support collaboration between public research (i.e. universities and research institutes) and the industry compared to public research and the public sector. The government should therefore consider the possibility to develop more effective and greater variety of transdisciplinary programmes and centres involving research groups from different disciplines, from one or several universities and stakeholders from the public sector. These research and innovation activities should not exclude participants from the business sector. Universities, whether alone or in collaboration with relevant public agencies, should also attempt to develop new learning arenas (programmes, centres, innovation projects) that connect researchers with public sector experts and policymakers in addressing societal needs. From this perspective, we welcome the new practice in the call for Centres for Research-based Innovation, in which the participation of the private and public sectors is mandatory in the proposals. NTNU and Trondheim´s *Universitetskommune* may serve as one example of how this can be done at a municipality level.

2. Universities ought to seek a better understanding of the various ways and channels they impact innovation in the public sector.

It is difficult to obtain accurate measurements of the effects university/public sector interaction will have on public sector innovation and its ability to address societal challenges. The systemic interaction and the spillovers are complex, and the effects are often long term. Universities and policymakers should nevertheless develop a set of indicators and qualitative evaluation practices that enables the identification of some of these effects, in addition to pinpointing areas for improvement. There should also be an increased focus on the role university candidates play in the development of public sector learning capabilities. This means that the role of students and candidates should be included in all relevant strategies.

3. The need to explore how university researchers within multidisciplinary and multiple stakeholder teams can contribute to identifying future challenges and opportunities for the public sector as a systematic and standard approach of policy development and experimentation within the public sector.

In collaboration with relevant partners, universities should develop new methods for strategy development. This kind of strategic learning should include methods for exploring different futures (foresight), by involving multi-disciplinary research teams and by including a wide variety of stakeholders and citizens, and for taking the need for sustainable and responsible research and innovation into consideration.

Bibliography

Bekkers, R., & Bodas Freitas, I. M. (2008). Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? *Research Policy,* 37, 1837-1853.

Bishop, K., D'Este, P., & Neely, A. (2011). Gaining from interactions with universities: Multiple methods for nurturing absorptive capacity. *Research Policy,* 40, 30-40.

Boardman, P. C., & Bozeman, B. (2015). Academic faculty as intellectual property in university-industry research alliances. *Economics of Innovation and New Technology,* 24, 403-420.

Broström, A. (2012). Firms' rationales for interaction with research universities and the principles for public co-funding. *The Journal of Technology Transfer,* 37, 313-329.

Bruneel, J., D'Este, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university–industry collaboration. *Research Policy,* 39, 858-868.

Cohen, W., Nelson, R. R., & Walsh, J. P. (2002). Links and Impacts: The Influence of Public Research on Industrial R&D. *Management Science,* 48, 1-23.

DAMVAD (2018). Evaluation of the Scheme for Research-based Innovation (SFI). In*:* NORWAY, R. C. O. (Ed.).

De Fuentes, C., & Dutrenit, G. (2014). Geographic proximity and university-industry interaction: tTe case of Mexico. *The Journal of Technology Transfer,* 41, 329-348.

Dornbusch, F., & Neuhausler, P. (2015). Composition of inventor teams and technological progress - The role of collaboration between academia and industry. *Research Policy,* 44, 1360-1375.

Fitjar, R. D., & Gjelsvik, M. (2018). Why do firms collaborate with local universities? *Regional Studies,* 52, 1525-1536.

Fontana, R., Geuna, A., & Matt, M. (2006). Factors affecting university-industry R and D projects: The importance of searching, screening and signalling. *Research Policy,* 35, 309-323.

Haas, A. (2015). Crowding at the frontier: Boundary spanners, gatekeepers and knowledge brokers. *Journal of Knowledge Management,* 19, 1029-1047.

Iglebæk, F., Nygård, G., Bruvoll, A., & Christian, G. (2018). Effekter av energiforskningen. In Impello (Ed.), Trondheim.

Knudsen, M. P., Tranekjer, T. L., & Bulathsinhala, N. (2017). Advancing large-scale R&D projects towards grand challenges through involvement of organizational knowledge integrators. *Industry and Innovation*, 1-30.

Lauvås, T. A. (2017). *The dynamics of university-industry collaboration: A longitudinal case study of research centers.* nos. 63-2017, Nord University Business School.

Lundvall, B. Å. (2007). National Innovation Systems—Analytical Concept and Development Tool. *Industry and Innovation,* 14, 95-119.

Núñez-Sánchez, R., Barge-Gil, A., & Modrego-Rico, A. (2012). Performance of knowledge interactions between public research centres and industrial firms in Spain: A project-level analysis. *The Journal of Technology Transfer,* 37, 330-354.

OECD (2019). *University-Industry Collaboration: New Evidence and Policy Options,* Paris, OECD Publishing.

Perkmann, M., Neely, A., & Walsh, K. (2011). How should firms evaluate success in university–industry alliances? A performance measurement system. *R&D Management,* 41, 202-216.

Perkmann, M., & Walsh, K. (2007). University–industry relationships and open innovation: Towards a research agenda. *International Journal of Management Reviews,* 9, 259-280.

Santoro, M. D., & Chakraarti, A. K. (1999). Building Industry–University Research Centers: Some Strategic Considerations. *International Journal of Management Reviews,* 1, 225-244.

Slavtchev, V. (2013). Proximity and the Transfer of Academic Knowledge: Evidence from the Spatial Pattern of Industry Collaborations of East German Professors. *Regional Studies,* 47, 686-702.

Steinmo, M., & Rasmussen, E. (2016). How firms collaborate with public research organizations: The evolution of proximity dimensions in successful innovation projects. *Journal of Business Research,* 69, 1250-1259.

Thune, T. (2011). Success Factors in Higher Education-Industry Collaboration: A case study of collaboration in the engineering field. *Tertiary Education and Management,* 17, 31-50.

Thune, T., & Gulbrandsen, M. (2014). Dynamics of collaboration in university–industry partnerships: do initial conditions explain development patterns? *The Journal of Technology Transfer,* 39, 977-993.

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ANNEX 2 - Notes on definitions of the notion of Innovation in this report

In this Annex, we present basic definitions of the various concepts of innovation we apply in this report.

In order for a new idea, model, method or prototype to be considered as part of an innovation, it needs to be implemented. Implementation requires organizations to make systematic efforts to ensure that the innovation is accessible to potential users, either for the organization's own processes and procedures, or to external users for its products. The requirement for implementation is a defining characteristic of innovation that distinguishes it from inventions, prototypes, new ideas, etc.

At a minimum, innovations must contain characteristics that were not previously made available by the relevant organization to its users. These features may or may not be new to the economy, society or a particular market. An innovation can be based on products and processes already in use in other contexts, e.g., in other geographical or product markets. In this case the innovation represents an example of diffusion. Innovation diffusion can generate substantial economic and social value, and is therefore of policy importance.
Hence, to a large extent, higher education institutions (universities) in general contribute to the extension of our cultural and knowledge frontiers, to new ideas, to the development of new technologies, inventions and prototypes by themselves or in collaboration with the industry. However, the key question is how exactly the universities contribute to the innovation processes in the business sector, in the public sector and in society in general.

Measuring the value creation from innovations
The realization of the value of an innovation is uncertain, and can only be fully assessed sometime after implementation. The value of an innovation can also evolve over time and provide different types of benefits to different stakeholders. Complementary measures and analytical strategies can be used to trace innovation outcomes after a suitable length of time. Thus, it is challenging to assess the importance and the extent to which universities contribute to the various phases of the complex interaction processes of an innovation process. Their inputs may sometimes be pivotal or even foundational for large impact economic and social innovations.

With these remarks in mind, we present the key definitions of innovation activities as suggested by the Oslo Manual 2018 for the Measurement of Scientific, Technological and Innovation activities.

OECD Definitions

In general, the term "innovation activity" refers to the *process,* while the term "innovation" is limited to outcomes.

Innovation in the business enterprise sector:
Innovation activity includes all developmental, financial and commercial activities undertaken by a firm that are intended to or result in an innovation for the firm.
A business innovation is a new or improved product or business process, or combination thereof, that differ significantly from the firm's previous products or business processes, and that has been introduced on the market or brought into use by the firm.
A product innovation is a new or improved good or service that differs significantly from the firm's previous goods or services, and that has been introduced into the market.
A business process innovation is a new or improved business process for one or more business functions that differs significantly from the firm's previous business processes, and that has been brought into use in the firm.

Short term	Details and sub-categories
Production of goods or services	Activities that transform inputs into goods or services, including engineering and related technical testing, analysis and certification activities to support production
Distribution and logistics	This function Includes: a) Transportation and service delivery; b) warehousing; and, c) order processing.
Marketing and sales	This function includes a) Marketing methods that include advertising (product promotion and placement, packaging of products), direct marketing (telemarketing), exhibitions and fairs, market research and other activities to develop new markets; b) pricing strategies and methods; and c) sales and after-sales activities, including help desks, other customer support and customer relationship activities.
Information and communication systems	The maintenance and provision of information and communication systems, including: a) Hardware and software; b) data processing and database; c) maintenance and repair; and d) web-hosting and other computer-related information activities. These functions can be provided in a separate division, or in divisions responsible for other functions.

Adminis-tration and manage-ment	a) Strategic and general business management (cross-functional decision-making), including organizing work responsibility; b) corporate governance (legal, planning and public relations); c) accounting, bookkeeping, auditing, payments and other financial or insurance activities; d) human resources management (training and education, staff recruitment, workplace organization, provision of temporary personnel, payroll management, health and medical support); e) procurement; and f) managing external relationships with suppliers, alliances, etc.
Product and business process development	Activities to scope, identify, develop or adapt products, or a firm's business processes. This function can be undertaken in a systematic fashion or on an ad hoc basis, and be conducted within the firm or obtained from external sources. Responsibility for these activities can lie within a separate division or in divisions responsible for other functions, e.g., the production of goods or services.

Table A2-1: Types and definitions of business innovation processes; source: OECD 2018

Degree of innovativeness

The *basic requirement* for an innovation is that it must be significantly different from the firm's previous products or business processes. Some forms of novelty, such as disruptive or radical innovations, in addition to some types of economic impacts, are difficult to identify within a limited observation period. Alternative measures of novelty, "innovativeness" and economic impacts that are easier to operationalize and measure include:

If an innovation is new to the firm only, new to the firm's market, or new to the world;
The expected potential to transform the market in which the firm operates; and
The expected potential to improve the firm's competitiveness.

Recently, there is a considerable interest in *business model innovations*. The Oslo Manual (2018), though avoiding metrics for this type of innovation, distinguishes between three types of comprehensive business model innovations in existing firms:
A firm extends its business to include completely new types of products and markets that require new business processes to deliver;

A firm ceases its previous activities and enters into new types of products and markets that require new business processes; and

A firm changes the business model for its existing products, e.g., it switches to a digital model with new business processes for production and delivery and the product changes from a tangible good to an information good.

Comprehensive business model innovations are of greater interest because they can have substantial effects on supply chains and economic production, transforming markets and potentially creating new ones. They can influence how a firm creates utility for users (product innovation), and how products are produced, brought to market or priced (business process innovations).

There may be some truth in the assertion that universities shape the content and direction of radical innovations rather than incremental innovations to a greater extent, but there is no claim to this consensus in the literature.

Innovation in other societal sectors – public and civic sectors

The general definition of an innovation for all types of units is as follows: An innovation is a new or improved product or process, or combination thereof, that differs significantly from the unit's previous products or processes, and that has been made available to potential users or brought into use by the unit.

Innovations in the general government sector
Many process innovations in the government sector draw on or are similar to innovations in the business enterprise sector, but service innovations often meet redistributive or consumption-related goals that are unique to government. A common characteristic of innovation in the government sector includes the frequent use of collaboration, including with organizations in other sectors, and the co-production of innovations. Of course, this is highly pertinent for the HEI sector.

The *absence of a market* is frequently cited as the major difference between the business and government sectors (Bloch & Bugge, 2013; Gault, 2012). The absence of a market alters both the incentives for innovation and the methods for measuring innovation outcomes. Without data on the cost or price paid for government services, outcome measurement has relied on subjective, self-reported measures, such as an increase in efficiency or improved user satisfaction (Bloch & Bugge, 2013).

More broadly, the study of innovation within government and the public sector has attracted a growing body of empirical research, motivated in part by the increasing demand for benchmarking the efficiency and quality of public services, as well as identifying the factors that contribute to desirable innovation outputs and outcomes. Many of these studies have adapted the guidelines in the previous edition of this manual to develop surveys of innovation in public administration organizations (Arundel & Huber, 2013; Bloch & Bugge, 2013), although more recent surveys have added questions explicitly designed for the government sector. This shift was driven by the need to collect data to support public sector innovation policy (Arundel et al., 2016). Other research has used various methodologies to examine innovation in education, health and social care services (Windrum & Koch, 2008).

De Vries, Bekkers and Tummers (2016) is a highly-cited literature review paper, attempting to systematize 181 papers and books on general government innovations with respect to the following five issues: (1) the definitions of innovation, (2) innovation types, (3) goals of innovation, (4) antecedents of innovation and (5) outcomes of innovation.

Social innovations
Non-profit institutions (NPIs) produce or distribute goods or services, but do not generate income or profit for the units that control or finance them, and they are

often non-governmental social institutions. Many NPIs seek to implement "social innovations", defined by social objectives to improve the welfare of individuals or communities.

Kleevey and Zaring (2018) define a *social innovation as a novel activity or organizational mode that is not, or at least not primarily, motivated by private gain or business logic*. Phills et al. (2008) define it as "a novel solution to a social problem that is more effective, efficient, sustainable or just than current solutions, and for which the value created accrues primarily to society as a whole rather than private individuals".

Little if any literature conceptualizes the role of the university in delivering social innovation, partly due to the recent emphasis on university involvement in profit-making and commercialization activities. Kleevey and Zaring (2018) are an exception to that.

The role of individuals
Individuals as members of one or more households can be involved in innovations. This can occur outside of regular employment, or through their work on a self-employed basis in unincorporated enterprises for which they are the sole or joint owner. Understanding and managing the impact of innovation on individuals in their roles as employees, asset owners and consumers is an important and understudied issue.

Bibliography

Arundel, A., Bloch, C., & Ferguson B. (2016). Measuring innovation in the public sector, OECD Blue Sky Forum 2016, Ghent Belgium, September.

Arundel, A., & Huber, D. (2013). From too little to too much innovation? Issues in measuring innovation in the public sector. *Structural Change and Economic Dynamics* 27:146-159.

Bloch, C., & Bugge, M. (2013). "Public sector innovation – from theory to measurement". *Structural Change and Economic Dynamics* 27:133-145.

De Vries, H., Bekkers, V., & Tummers, L. (2016). Innovation in the Public Sector: A systematic Review and Future Research Agenda. *Public Administration,* Vol. 94, issue 1, pp. 146-166.

Gault, F. (2012). User innovation and the market. *Science and Public Policy* 39:118-128.

McKelvey, M., & Zaring, O. (2018). Co-delivery of social innovations: Exploring the university's role in academic engagement with society. *Industry and Innovation,* Vol. 25, issue 6 pp. 594-611.

OECD (2018). The Measurement of Scientific, Technological and Innovation Activities - Oslo Manual 2018. Paris.

Phills Jr, J. A., Deiglmeir, K., & Miller D. T. (2008). Rediscovering Social Innovation. Stanford Social Innovation Review. https://ssir.org/articles/entry/rediscovering_social_innovation.

Windrum, P., & Koch. P. M. (2008). Innovation in Public Sector Services. Edward Elgar, Cheltenham.