University Innovation Indicators

Final report from NTNUs pilot project

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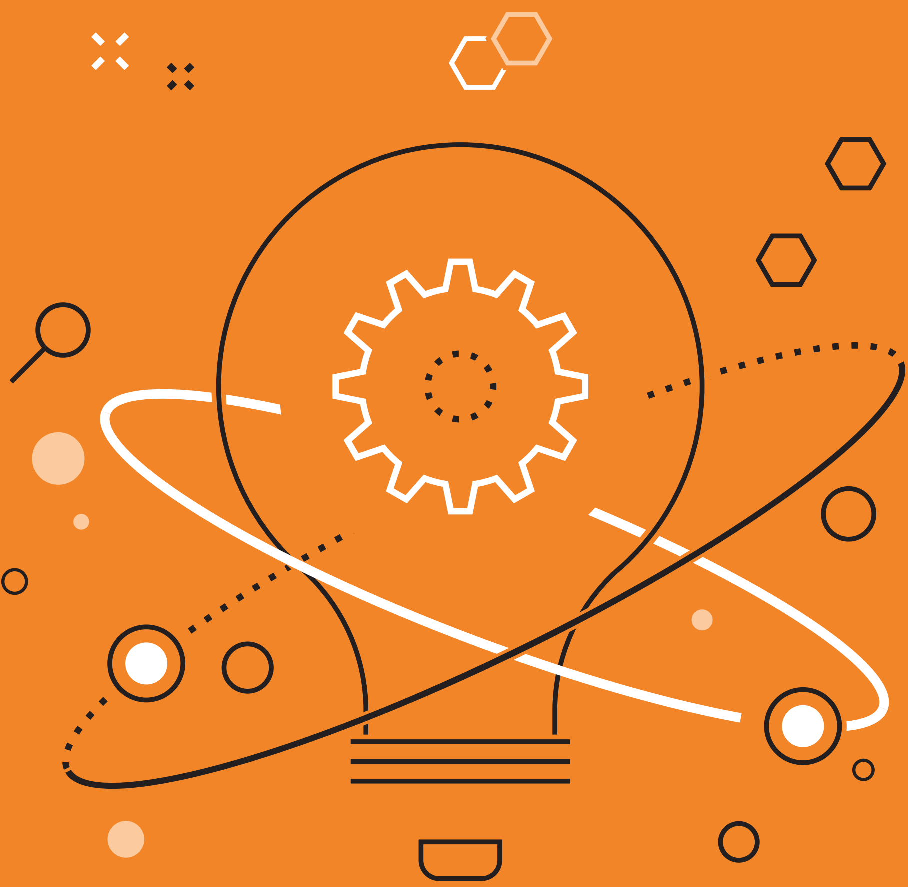

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Content

Preface

NTNU's comments on the report "University Innovation Indicators – Final report from NTNUs pilot project".

This report is a direct response to the challenge posed by the Norwegian Ministry of Education and Research to NTNU. The challenge is about the need to produce indicators capturing a broader array of innovation channels and impacts from the Norwegian higher education institutions (HEIs) than just indicators on commercialization of R&D. To address this challenge, I commissioned a research project with the goal to develop suitable innovation indicators for HEIs with NTNU as testing bed. The pilot project recommends 15 indicators, 2 indicators on innovation-oriented external funding sources, five indicators on various types of people interactions, three indicators on innovation networks and five indicators on academic and student entrepreneurship.

The indicator challenge from the Ministry echoes the growing societal expectations that Norwegian HEIs must improve the profiling of their innovation impacts and in that respect, perhaps, they should develop more strategic approaches to innovation as well as more flexible career paths and incentives to better balance innovation and academic careers in the future. The report emphasizes the importance of producing quantitative indicators as one method needed to coordinate available funding sources, people and networks into a dynamic innovation ecosystem.

HEIs have also a key role to play in the restructuring process of the Norwegian economy away from oil and gas and towards a more sustainable development. There is ample scholarly evidence that these transitions can only be developed in an open and interactive innovation ecosystem where funding sources, people and networks are the pivotal raw ingredients. 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 contribute to in many different modalities and through different channels. Academic entrepreneurship and university spin-offs are of course important innovation channels, but they only constitute a smaller part of universities´ overall innovation contribution to society. The pilot project was challenged to assess the feasibility of applying a more diversified set of indicators showing a wider university contribution to innovation.

An important insight from the pilot project is that specific initiatives and activities for promoting innovation and value creation adopted by one department within NTNU are not necessarily suitable for other departments or even other universities. Norwegian universities can certainly learn from each other, but the important point is that each institution, faculty and faculty department ought to develop their own innovation strategies on the basis of the strengths and opportunities in their innovation profiles. The analysis of the selected innovation indicators clearly shows a large variety of indicator profiles between departments within NTNU, even between departments within the same faculty at NTNU.

The report also points to considerable methodological challenges in measuring innovation in 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. Yet, such contributions are difficult to capture through quantitative indicators. This is an argument for more research on this area and for documentation by the means of narratives, i.e., innovation impact cases.

Student-led entrepreneurship is also not well-captured in the indicators of this pilot project and yet we have an ambition to better measure and document impacts of student-entrepreneurship activities in the future, such as NTNU ideas, patents, and spin-offs stemming from NTNU Discovery and SPARK*.

NTNU is experiencing an increasing demand for R&D collaboration from both the private and public sectors. In particular, university-industry research centers, such as the Center for Research-based Innovation (SFI) and the Centers for Environment-friendly Energy Research (FME) develop long-term relationships and deliver new knowledge, prototypes, new methods, new technologies 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. And yet, one of the important findings in this report is that this rich array of innovation activities and impacts is not always documented in its full scale and scope in the annual reports from the SFIs.

In conclusion, we must learn to better document and communicate how universities create value in our societies. This is already a prerequisite for obtaining research funding, both within the EU's Research and Innovation programs and within national research and innovation policy instruments. The ability to systematically think and coordinate actors, activities and resources for enhanced innovation impact is a key skill for the future HEIs and their departments.

Trondheim, Desember 2022

Toril Nagelhus Hernes, Pro-Rector for Innovation, NTNU

Part I
The new set of innovation indicators for HEIs

Objectives and scope of the pilot project

In recent decades, the scope of innovation in contemporary higher education has undergone a surfeit of unforeseen changes. These changes, occasionally subsumed under the label of "open innovation",[1] have garnered significant scholarly criticism regarding both the conceptual clarity and the practical shapes of the agenda of innovation. Challenges to the innovation measures proliferate: theoretical imprecision, implementation deficiencies, and lack of comparable, replicable, and reliable data on the field of university-driven innovation[2]. And, to further compound the discontents surrounding innovation, the problem is occasionally argued to run much deeper, to the very way we understand and measure the effort towards innovation.

The tenets and practical challenges that surround particularly the measurement of university-driven innovation have not escaped scholarly scrutiny across disciplinary bounds. In fact, much scholarship now concedes that perhaps the thorniest, yet prevailing challenges is the absence of indicators that systematically capture impact of innovation originating from the Higher Education Institutions (HEI), beyond standard scientific output (i.e., numbers of publications and citations) and specific commercialization data. Scholarly inquiry, spanning from traditional research organizations such as the OECD (2019) to newest scholarly attempts from European University Association (EUA 2018), has repeatedly drawn attention to the difficulties surrounding both the quantification and comparability of innovation efforts in the university sector, as well as the ability of existing innovation metrics to factor in the less directly observable, qualitative cases of innovation and their longer-term societal ramifications in their impact.

In response to this set of challenges a recent study (NTNU 2019) addressed this issue and provided a set of 45 academia related innovation indicators (see Annex 2). This work constitutes a starting point for this pilot project to select and produce a more contained number of indicators that - individually and taken together - portray a fair and broader picture of HEIs contributions to innovation.

The rationale of innovation indicator efforts is divided between two logics. The first category of indicators dubbed as indirect contributions (activities and processes), casts light on the skills, cultures, and interactions that occur in the areas of innovation. These ideas span from the integration of innovation in teaching and the generation of new ideas to the collaboration, networking and mobility outside the walls of academia. Conversely, the second category of indicators entitled as direct contributions (impacts) seeks to capture the more standardized aspects of innovation, often understood as the commercialization outputs and the tangible improvements of industrial activities and performance.

The pilot project adopted the classification of indicators in NTNU 2019, refined it and on this basis, suggests 15 indicators proposed as a permanent set of innovation indicator reporting in the future.

The theoretical perspective behind these 15 indicators is based on the idea of the university innovation ecosystem where many types of resources (people, funding, networking) interact in an *open and dynamic environment* that may or may not be consciously governed and shaped by the HEIs themselves.

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[1] Chesbrough, 2003; Dahlander & Gann 2010; Markman 2016.

[2] Gault 2012.

Definitions of Innovation

In order for a new idea, model, method or prototype to be considered as "innovation", it needs to be economically and/or societally useful. This mandatory utility aspect requires organisations to make systematic efforts to ensure that the innovation is accessible to potential users, either for the organisation's own processes and procedures, or to external users for its products.

At a minimum, *innovations* must contain characteristics that were not previously made available by the relevant organisation 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 that were already in use in other contexts, for instance in other geographical or product markets. In this case, the innovation represents an example of incremental adjustments and diffusion to new markets.

Higher Education Institutions (HEIs) contribute to a large extend 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. The key question is, however, how exactly the HEIs contribute to the *innovation processes* in the business sector, in the public sector and in society in general.

In general, the term "innovation activity" refers to the *process leading to innovations, i.e., innovation processes,* while the term "innovation" is limited to outcomes. This is an important distinction throughout this report and in the next paragraph we present how the Oslo manual (OECD 2018) defines key concepts, such as "innovation activity". The Oslo manual is the internationally established methodology for collecting and using innovation statistics in the business sector worldwide. It includes definitions of basic concepts, data collection guidelines, and classifications for compiling innovation statistics:

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 differs 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 on 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.

There is also 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.

- A firm changes the business model for its existing products, for example 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 in the last years of great 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).

Measuring the economic value creation from innovations
The realisation of the value of an innovation is uncertain and can only be fully assessed sometime after implementation, often decades after its conception. The value of an innovation can also evolve over time and provide different types of benefits to different stakeholders. Complementary measures and analytical strategies must often be employed to trace innovation outcomes after a suitable length of time.

Therefore, it is challenging to assess the importance and the extent to which HEIs contribute to the various impact phases of the complex interaction processes of an innovation process. Sometimes their inputs may be pivotal or even foundational for large impact economic and social innovations, but this contribution may be very difficult to trace and document.

There may be some truth in the assertion that HEIs shape into a greater extent the content and direction of radical innovations than incremental innovations, but to this claim there is not yet a consensus in the academic literature.

Innovation in other societal sectors – public and civic sectors

There is not yet an established set of definitions of what innovation is in the public and civic sectors, comparable to that of the Oslo Manual for the business sector. There is however an increasing interest in understanding the breadth and the types of innovation activities and innovation impacts in these sectors.

Innovations in the general government sector
Many process innovations in the government sector draw on or bear similarities to innovations in the business enterprise sector, but *service innovations* often meet redistributive or consumption-related goals that are unique to government. Common characteristics of innovation in the government sector include the frequent use of collaboration, including with organisations in other sectors, and the co-production of innovations.

The absence of a well-defined market is frequently cited as the major difference between the business and government sectors. The absence of a market alters both the incentives for innovation, the incentives for how intensively one should innovate 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 and Bugge, 2013).

The study of innovation within government and the public sector more broadly 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. De Vries, Bekkers and Tummers (2016) authored a highly cited literature review paper, attempting to systematize research 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) defines a social innovation as a novel activity or organisational mode that is not, or at least not primarily, motivated by private gain or business logic. There is a large number of other definitions of social innovation in literature, a fact that indicates the growing interest in and the policy importance of the social innovations. Still, little literature conceptualises the role of the university in delivering social innovation. Several researchers have argued that the third mission role of HEIs has been largely construed in the *commercial sense of knowledge* and *technology transfer*, in what has been labelled the "entrepreneurial university" while their contributions to social innovations has been largely neglected. Lately, however, a growing number of research has been conducted on higher education living labs and science shops. Living labs and science shops are aimed at creating an open and user-centered platform where the resources of the university are leveraged to co-produce knowledge and innovations that are open and available for the use and benefit of the entire society. They are examples of how HEIs contribute to *social innovation processes*.

The University innovation eco-system concept

The discussion above and additional recent scholarship in the field of innovation (Erdil et al. 2018; Fasnacht 2018; Grandstrand and Holgersson 2020; Leceta & Könnölä 2019; Oh et al. 2016; Reichert 2016; Schiuma & Carlucci 2018; Viitanen 2016), seeked to move beyond the division between direct and indirect innovation activities in an attempt to illustrate the deeper and fundamental connection between the structures and the processes of innovation.

An important premise for the future of knowledge economies and societies is that the next decades will be clearly driven by all the aspects of *sustainability and digitalization*, including AI. To embrace these changes the economic and policy actors need to move from traditional business models to more flexible and agile ones. Universities contribute substantially to these economic and societal transformation through their open innovation ecosystems. These ecosystems are complex, iterative, and barely controllable. We currently observe a number of industries experiencing rapid structural changes, new market entrants, and intermediaries with disruptive business models that are increasingly embracing open innovation. Speed, flexibility, reliance, and efficiency have all become equally important factors for success or failure and universities need not only to adapt but also to proactively provide society with the necessarily skills, knowledge, cultural understanding and people that will contribute to reap the benefits and to mitigate the adverse effects of the new age coming.

On that basis, we suggest directing the attention of this pilot project to the three basic elements of any innovation ecosystem: the finances, the people, and the networks. In that respect, it seeks to escape the confines of the distinction and eventual hierarchical thinking between direct and indirect contributions and, rather, draw attention to the creative interplay between the three elements of innovation. By means of this approach, our study seeks to examine the connections in the way that structures, which are more stable, path-dependent, and deeply weaved into the fabric of innovation (such as e.g. a TTO office) can interact with processes which are more dynamic, elusive, and transient (such as the disclosure of an idea).

As a feasibility study, the main objective of this project is to deliver a more crystalized, condensed, and systematic set of indicators for HEIs which meet the international benchmarks for solid indicators (cf. OECD 2019; World Bank 2016) and follow the SMART criteria for internal and external validity: specific, measurable, attainable, relevant, and time-based.

Ultimately, the pilot seeks to establish a new set of innovation indicators which will surface a new set of innovation indicators which will capture the landscape of HEIs innovation efforts and allow for international visibility and, ultimately, inform our understanding of both NTNU's and other Norwegian HEIs socio-economic and societal impact and its role in its broader innovation landscape in a most efficient and cost-effective manner possible.

What to measure – structural versus procedural indicators

The rationale and exact empirical practices for innovation reporting in universities has been by and large fragmentary and undertheorized. Recently, in a recent report from the US on Innovation Impact (Cullum Clark et al. 2020:8), the innovation impact was conceptualized and quantified in terms of four categories and nine variables: commercialization impact (New patents issued, new licenses, license income), entrepreneurship impact (spinout companies & licenses to spinout companies), research impact (paper citations & patent citations) and teaching impact (new STEM doctoral students and new STEM bachelor´s and master´s students).

The OECD approach (2010) presents a more nuanced and sophisticated approach, including not only innovation indicators such as economic growth, intangible assets, and patents, but also softer and less readily measurable aspects of innovation, such as (inter-)national cooperation, the convergence of scientific fields, interdisciplinary research, and education and training.

Nonetheless, aspects of social innovation and public value creation escape the span of such metrics, disallowing fields with lower technology readiness level and not directly commercializing direction (especially humanities and social sciences) to demonstrate the positive innovation externalities that they offer to their regional ecosystems, from both university and industrial directions. Qualitative and quantitative studies from a social science perspective (Benneworth et.al. 2016, Benneworth and Jongbloed 2010; Gullbradsen and Aanstad 2015) have repeatedly pointed to this gap of research with regards to the impact of innovation from "softer" disciplines and less established- yet consequential- innovation channels. What is more, this line of inquiry has also pointed to the fact that innovation impact spans beyond economic growth or academic credentials, but encapsulates also social innovation and public value creation, the impact of which is less directly measurable and reported in innovation outcomes and results (Ansel and Torfing 2014; Arundel et al. 2019; Bloch 2011; Brix 2017; Kelly et al. 2002).

For the purposes of this pilot project, we shall therefore pursue a slightly different and broader analytical perspective. Based on a growing body of scientific work on behavioral and cognitive science regarding the issue of priority-setting in decision sciences and governance of organizations (Brunsson 2007; Gutierez et al. 2008; Koechin 2020; Riedl, Brandstätter, & Roithmayr 2008; Patil et al. 2014; Marchau et al. 2019), we shall distinguish between two types of innovation indicators and akin innovation decisions: *structural* and *procedural.* On the one hand, structural approaches represent the lion's share in the research of innovation indicator and describe the relation between information stimuli (input) and decision responses (output) to infer the decision strategy used in order to achieve an envisioned innovation outcome (Abelson and Levi 1985; Einhorn, Kleinmuntz, & Kleinmuntz 1979; Ford et al. 1989; Reidi et al. 2008). In the structural paradigm, innovation indicators are used in order to capture quantifiable metrics and data with concrete outputs, such as the standardized commercialization data that despite their preponderance, do occasionally invite significant challenges regarding their depth, innovation scope and their practical import (see Gault 2014: 441-464; World Bank 2011).

The rival approach to innovation indicators, identified as the procedural approach (Birchall et al. 2011; Dziallas and Blind 2019; Eling and Herstatt 2017; Klenner et al. 2013) seeks to uncover some of the dynamics between inputs and impacts. Procedural approaches seek therefore to unravel network dynamics, collaborations, and emergent activities which defy easy quantification and/or estimation of their impact contributions. Ultimately, by surfacing the procedural dynamics in the process of innovation and within the university eco-system theoretical perspective, we aim to compile data which allow for new innovation indicators to emerge which pay attention to innovation eco-system human dynamics.

Demarcating indicators for innovation activities in HEIs

There are three important demarcation zones that ought to be addressed in our endeavour to justify the validity of any set of innovation indicators for HEI, most preponderant the demarcations against the domain of research, education and the complementary relations with indicators on TTO commercialisation activities.

Overlapping with research indicators

Indicators for innovation and impact of research are routinely classified under two scholarly categories. The first category is standardly referred to as science and technology indicators (STI). This line of statistical measurement and econometric work, borne out of the need for rules towards the reliable and comparable measurement of innovation in research and development (henceforth R&D), gave rise to the first manual for the collection and interpretation of R&D data, the *Frascati Manual* of 1963 (OECD 2002:151, Gault 2014:41) and a large host of subsequent manuals following and refining these standards of innovation measurement, most prominent of which remains the *Oslo Manual* (currently in its fourth edition- see OECD: 2018). These types of indicators are not interesting in the setting of this pilot project, although several of the innovation indicators we suggest for inclusion in the pilot constitute subsets of the STI-indicators for the Higher education sector. Our idea here is to exploit the finer grained information that the HEIs do possess on funding and people that directly relates to innovation, and not mainly to research or education.

Secondly, an established set of indicators for measuring impact of research *are scientometric indicators*. Scientometrics, a rapidly developed field within science and public policy, has been defined as the "quantitative study of science, communication in science, and science policy" (Hess, 1997), with an emphasis on analysis of the development and mechanisms of sciences through statistical mathematical methods. The field of scientometrics has a recent history. It has evolved from the study of indices for improving information retrieval from peer-reviewed scientific publications (commonly described as the "bibliometric" analysis of science) to comprise other types of documents and information sources relating to science and technology. These sources may include statistical and curated data sets, web pages and social media metrics (cf. Hicks et al. 2015; Shibayama and Wang 2020). Recent evolutions and minable data points in the field of research innovation and impact include the development citation metrics (e.g. Altmetric scores, Social Science Citation Index, Category Normalized Citation Impact (CNCI) etc.), readability measures and scoring for papers (e.g. Flesch Reading Ease (FRES), Flesch–Kincaid (FKS), Gunning Fog (FOG), Simple Measure of Gobbledegook (SMOG) and Dale–Chall (DCS)), as well as the identification and analysis of citation networks (cf. Hicks et al. 2015; Wang 2013, 2016; Wang et al. 2015).

Scientometric indicators, as combined with STI indicators, contribute much to recent universal university efforts to standardize, collect, collate, report and analyze a wide gamut of science, technology and innovation activities by providing evidence on a selected set of science and technology (S&T) outcomes and ultimately the innovation and impact of research efforts. Despite their relative relevance for the field of innovation studies, however, and their importance for understanding some aspects of the innovation and impact of research in society, this pilot study will not harness such data. This is because we seek to produce *novel* indicators that are relevant for capturing innovation dynamics not revealed by scientometric indicators. Having said that, this artificial distinction between research and innovation indicators is not sustainable from an organizational perspective and in the future both research and innovation indicators must be compiled and analyzed together for strategic decision-making purposes.

Overlapping with education indicators

As mentioned, the scholarship concedes that the development of reliable indicators for innovation performance within HEI education is still at its infancy (Loukkola et al. 2020, OECD 2019, NTNU 2019b). Yet significant efforts have been made to measure the quality and innovativeness of the educational process. These are divided into two segments: learning indicators and teaching indicators.

Efforts to create indicators with regards to learning include the development of learning outcomes for each course or an educational programme at the university sector. Such efforts have been initially shouldered from OECD's "Assessment of Higher Education Learning Outcomes" feasibility study (AHELO 2013) and, more recently, from the European Commission's "Measuring and Comparing Achievements of Learning Outcomes in Higher Education in Europe" (CALOHEE 2020), both of which were designed to allow for testing the performance of students -transnationally- on subject level. The reliability and replicability of these efforts for measuring and indexing learning remains still inchoate.

On the front of teaching innovation metrics, the lack of indicators is also noteworthy. Standardly, rankings and quality assurance agencies reflect on teaching quality using "student satisfaction" as an indicator in their work, typically captured through student surveys. These surveys, conducted either by ranking providers (e.g. U-Multirank and THE Europe Teaching Rankings) or through the assigned national statistics agency (e.g. NIFU) ask specifically both on the opportunities for interaction with teachers and on the overall learning experience. Recently, online teaching platforms and learning databases (e.g. Canvas, Blackboard etc.) are also harnessed for yielding data on what has been identified as "learning analytics", namely, the degree of student engagement and interaction within a course's trajectory (c.f. Kie Daniel 2016; Lester et al. 2018). This recent development, harnessing on the power of big data and AI, is also considered as a promising avenue for understanding the dynamics of educational innovation and learning practices within institutions.

In a nutshell, indicators and proxies for capturing and assessing the quality and innovativeness of education span across factors such as the following: student and staff numbers, student progression (number of degrees awarded, funding formulae, graduation rate and time to graduation, drop-out and retention rates), as well as indicators for graduate employment (e.g. U-Multirank's indicator of contact with the work environment, a composite indicator reflecting on number and student participation in internships) and internationalization (e.g. language of instruction).

The overall degree of overlap of innovation processes with the core of the educational sphere is significant, particularly with regards to indicators for graduate employment and entrepreneurial preparedness and mind-setting of students. Cognizant of the multitude of data on this topic and its substantial promise, this pilot project suggests to only focus on developing education/student innovation indicators, namely, harnessing data on student-driven innovation practices across fields and particularly within underexamined fields of innovation practices. Focus on student-driven innovation data will yield riveting insight into the process and the dynamics of innovation eco-systems in academia, as well as its prospects for surfacing the potential of these innovation indicators to link more closely the learning environments with student-driven commercialization. In addition to these indicators, this pilot project will only focus on indicators measuring people mobility among faculty members as well as PhD employability and direct collaboration between students and the industry. All other indicators measuring student and educational activities, irrespective to how important they actually are for the governance of all modern academic organizations, they do belong to the realm of education indicators and as such are not viewed as *novel* innovation indicators to be included into this pilot project.

HEI-innovation is a broader phenomenon than commercialization of research results

In the wake of a substantial mass of scholarly efforts on innovation in universities (for an overview, see Kaloudis et al. 2019, Xu et. al. 2020), researchers and academic practitioners have been confronted with a persistent dilemma in the monitoring and evaluation of innovation and its most representative indicators. On the one hand, several studies point to the understanding of innovation as a broader, holistic phenomenon which carries the epiphenomenal attributes of an ecosystem (for recent overviews of this approach, see Morris et al. 2017; Talmar et al. 2020). In this line of reasoning, innovation has been conceptualized and operationalized as a non-linear system of interactive actors and activities, which in turn cluster into specific patterns and features within given networks. These patterns, broadly subsumed under different interim metrics, are rendered meaningful through a long-term perspective which endorses iteration and process-based thinking as its main attributes.

On the other hand, the standard and most predominant models for measuring innovation in the higher education sector are inventoried under the commercialization indicators of a university. These are a) patenting (applications and filing); b) licensing (as a measure of the extent to which patent production is economically useful and marketed); c) HEI academic entrepreneurship through spin offs, incubation hubs and start-ups can be spearheaded by either students or faculty members, usually in collaboration with societal and industry stakeholders. Due to their wide scope and straightforward measurability potential, these indicators on commercialization outputs have repeatedly attracted significant scholarly and science policy interest for their impact and implications to both academic employees and students (see Fabrizio 2007; Mathisen and Rasmussen 2019). This scientific inquiry, driving political decision-making on national priorities and economic competitiveness in Europe and the OECD zone, remains a topic of recurrent interest.

In Norway, HEIs also measure the number of new innovation ideas (i.e. DOFI-filings). This is an interesting indicator to analyse in this pilot project as a proxy of the creativity generated within a specific HEI innovation ecosystem.

Collecting extant information on commercialization metrics are relatively easily accessible and we shall therefore include these indicators in this pilot project in order to provide a more complete picture of HEI innovation foot-prints. Having said that, there is a need for a more encompassing and systematic developmental work in order to produce more precise, more robust, and comparable R&D commercialisation indicators in Norway and abroad (Kaloudis et al. 2019, Chapter 5).

Benefits and the potential purporting use of the indicators

Due to the velocity, high cognitive load, and complexity of innovation environments, the ability to construct and frame decision-making priorities for what constitutes an “innovation activity” and, subsequently, “innovation impact” is fraught with indeterminacy. On the one hand, standard innovation metrics do capture several tangible and quantifiable aspects of academic innovation activities, such as publication impact, commercial or pecuniary activities, and educational accreditation or student progression. However, the extent to which the chain of cause and effect between an innovation activity and innovation impact is yet to be unambiguously clarified and evidently is not addressed in this pilot project.

Having said that, the levels of technology readiness and the familiarity of an academic environment with innovation spans across a large continuum, from the initial inception of an idea to its full maturity and dissemination (Engel 2012; Jacobsen et al. 2016). In light of this, the indicators we propose in this pilot project seek to reflect and expand upon the innovation levels of each faculty setting, tailored around the Nordic setting and the particular path dependencies of NTNU.

Cost-Benefit Analysis assessments of Indicators: Criteria

Our assessment of the degree of usefulness of individual indicators builds upon three main factors/criteria. The first twin set of factors is the relative information value (benefit) on the one hand and ease of retrievability (cost) on the other. By information value we understand the reach and interconnectivity an innovation activity has in the innovation eco-system. By ease of retrievability, we understand the extent to which a dataset can be collected and aggregated. The third factor is the degree of disciplinarity or domain-knowledge specificity of an indicator. This translates into the extent to which an indicator captures information only within a specific discipline or whether it carries significance across disciplines. That factor of disciplinarity can cast light on the comparability between faculties and allow for a deeper understanding of the intrinsic and extrinsic aspects of innovation in the knowledge economy.

Cost/Benefit	Low	High
Low	They will be included if relevant	Important indicators to identify in the pilot
High	Not interesting type of indicators	Careful selection of some few of those

Figure 1. Visualization of Cost-Benefit Assessment Model

By virtue of this model, our analysis aims to identify indicators that are low on production costs, yet high on information content. Ultimately, our analysis seeks to strike an equilibrium on the rates of return between the two antinomical forces of cost and benefits, but always with a view to elevated quality in the collection, interpretation, and social influence of the concentrated innovation efforts.

Selection strategies for the production of indicator data in the pilot

Standardly, the most salient metrics of innovation and their akin indicators measure on metrics such as quantity of spin-offs, the volume and quality of intellectual property generation and research income generation. However, in response to the growing consensus on the importance of diversifying the data points and overall quality of innovation data, our approach includes 14 selected departments from 8 faculties of NTNU.

The benefits from such an experimental approach (i.e. controlling for diversity) to the collection of innovation indicators are manifold. First, such an approach can elicit and subsequently prioritize the issue of visibility in the creation of innovation indicators. As much empirical scholarship in the field of innovation studies has showcased (Leonardi 2014; Wooten and Ulrich 2015), the ability to create visibility around knowledge transfer activities and their innovation has a unique impact across competitive innovation arenas, and is evidenced to carry significant consequences in the formation and continuous establishment of knowledge transfer. The second- and ensuing- benefit from this approach, which could become manifested after the *establishment of visibility around innovation* would be the establishment of protocols and guidelines for internal governance, which would be designed to boost innovation performance in the future. Certainly, the establishment of reliable metrics for innovation performance is still at an embryonic stage, and more research is required as to establish scholarly consensus as to what counts as high innovation performance, especially beyond commercialization outputs (Apa et al. 2020; Birchall et al. 2011; Dettenhofer et al. 2019; Huang and Chen 2017; Kaloudis et al. 2019; Ye et al. 2020). However, the consensual establishment of guidelines for boosting innovation performance can yield high dividends in the procurement of academic innovation and the establishment of a more sophisticated innovation ecosystem.

The pilot set of innovation indicators

On the basis of the demarcation criteria listed above and the cost-benefit considerations that shape and limit the scope of this pilot project we suggest investigating more closely a list of 15 procedural innovation indicators seeking to measure strengths and weaknesses of four fundamental dimensions of academic innovation ecosystems, namely the:

a) **Direct commercialization results** (patents, IPR-licensing, spin-offs) and including DOFI-filings and non-pecuniary agreements for licensing of IPRs.
b) **Funding**: the ability to attract innovation funding.
c) **People**: the complex interactions of people engaged in HEI innovation activities
d) **Networking**: the number and the reach of the networking activities between the academic environment, economic actors, and the broader society.

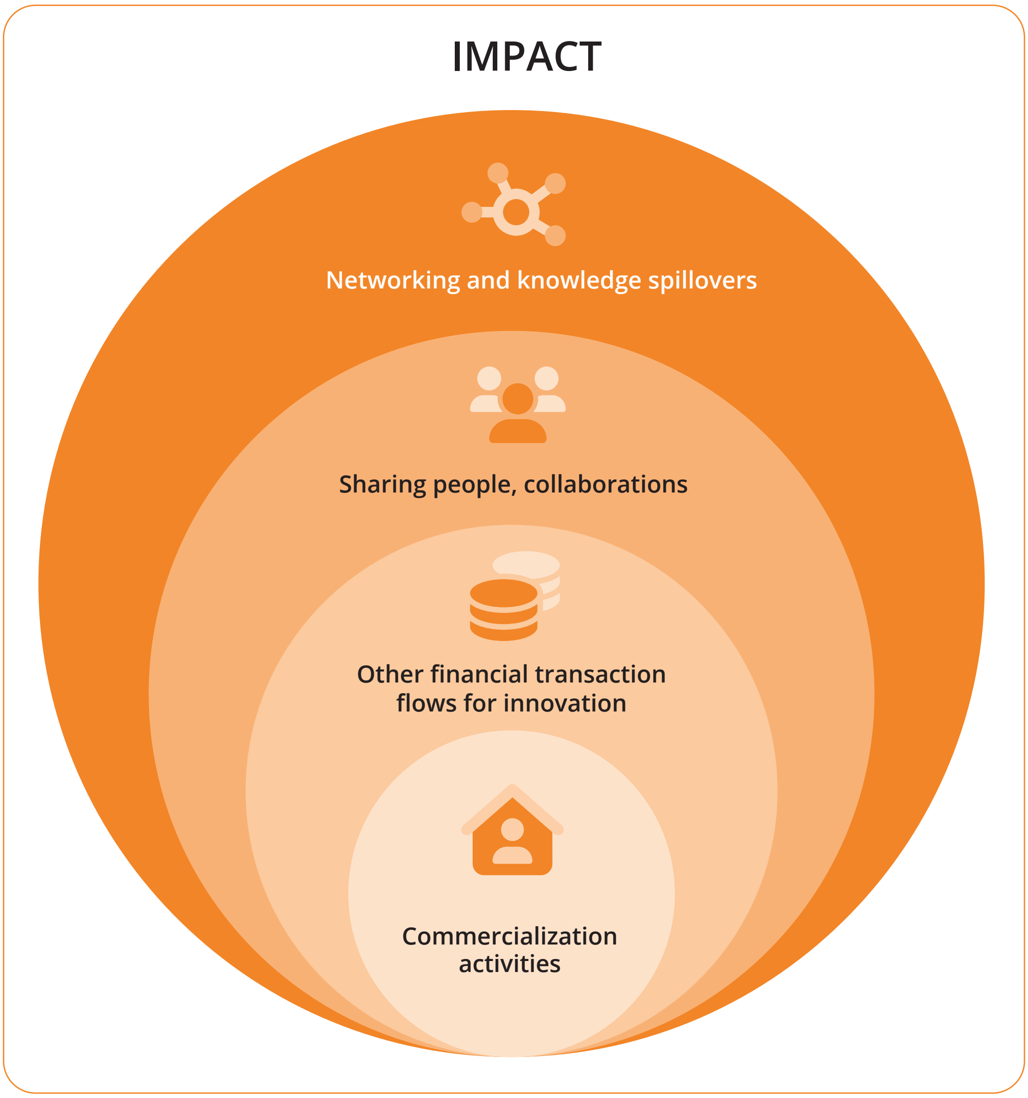

Figure 2. Depiction of the measurable layers of innovation impact, knowledge co-creation and networking and knowledge spill-overs. The larger the layer the more difficult the measuring of the related activities and presumably the opaquer is the impact.

The idea behind the Figure 2 is to show that the innovation impact of the HEIs is in many studies assumed to be much larger than that that is possible to capture with traditional commercialization indicators and other financial data. The more dense, fuzzy and multi-modal the interaction patterns between HEIs and the society, the larger the plausible impacts of knowledge spill-overs seems to become and, concurrently, the harder it is to measure this impact. This is one of the reasons why *procedural type of indicators of flows and people interactions and networking* may provide a richer description of how ecosystems work and differ.

The indicators we suggest in the next chapter just represent a first attempt to illuminate some of these questions. They are included because they do not clearly belong to the domains of research or education indicators, which are more dominant in the peer-reviewed literature on the topic. Second, as per our assessment model, these indicators are selected from the point of view of a balancing costs for producing them against the overall informational gains. As per Gault (2013),[3] given the high costs of producing innovation indicators and the subsequent collection of innovation data, there is a common trade-off between the utility of an indicator and its cost of production. In that respect, our study aimed to strike a balance between these two dimensions. In general, there is a limited or no previous academic literature for many of those indicators, but a number of them are also suggested on the belief that they capture other correlated innovation activities, as well as the cultural spirit encapsulated in the activities we are measuring. Yet, despite the fact that we indeed we find some evidence of correlation between indicators in our data, there is still no extensive evidence for this claim and in fact the issue of the informational reach of the suggested indicators is exactly one of the important questions that we ultimately must investigate in the future.

[3] Cf. particularly Gault 2013 pp. 441-464 on the challenges and unresolved issues of establishing innovation indicators.

Detailed Description of the final set of Innovation Indicators

1. and 2. BOA-Income in total and BOA directly from funding that has not research as its main goal (innovation-driven external funding)

The rationale for this indicator postulates that a high proportion of external funding income (BOA) involving diverse activities and funding sources indicate a more intense and deeper relationship between the university and the national industry, health authorities and public and regional sectors which spans beyond traditional research funding streams. The data source is NTNU data from the BEVISST database and an institutional questionnaire. Its computation will be double, divided by total BOA and then by total faculty staff in the respective department.

3. Job placement of NTNU PhDs

This indicator captures the job placement of NTNU PhDs across sectors. The rationale for this indicator is that the employability and exact positioning of NTNU PhDs in the labor market may reflect the attractiveness and relevance of such research-based innovation for non-academic milieus, and provide insight into the procedural aspects of innovation, as evinced by the patterns underpinning the career trajectories of PhDs. In particular, The placement of doctorate degree holders in various types of employment is a reflection of the active knowledge transfer links of the academic community to the broader labour market. The data source for this indicator is NTNU's register for student progress, as well as institutional surveys from NTNU's akin faculties. The computation for this indicator will occur as a survey of Position and number of NTNU PhDs divided by each sector's aggregate employment numbers.

4. Industrial PhDs (Nærings-PhD and offentlig-PhD)

This indicator captures the absolute number of Industrial PhDs (funded by either industry or other non-academic stakeholders) by absolute number and by faculty staff. The rationale for this indicator is that the attractiveness of NTNU as a study location for these PhD candidates at the forefront of competitive innovation may reflect the attractiveness and relevance of such research-based innovation. The placement of Industrial PhDs is a reflection of the relevance, active collaboration and knowledge transfer links of the academic community to the involved organisations. The literature points clearly to the fact that this measure is the preferred one amongst companies which do not want to cooperate with others in key competence areas. The data source for this indicator is NTNU's potential registers for alumni information, with the possibility of gathering data also from the Research Council of Norway. The computation for this indicator will occur as a survey of the number of Industrial PhDs within NTNU divided by the absolute NTNU PhD number and faculty staff numbers.

5. Adjunct Research Positions (II-er stillinger - sidegjøremål) from NTNU's academic roster to private sector (including creative/cultural industries), public sector (excluding health), research institutes, health sector, abroad

This indicator captures the adjunct research positions of NTNU academics to the entire spectrum of non-academic activities. The rationale for this indicator is that the more research activity is carried out in tandem between external partners from industry and the academic sector, the more likely it is that knowledge transfer and meaningful innovation activity takes place between academia and business. The data source for this indicator emanate from an institutional questionnaire and its level are to be aggregated to the institutional and potentially also on the faculty level. The computation for this indicator will occur as a survey of the number of Adjunct research Positions divided by the total number of full-time faculty.

6. Adjunct Positions (Professor II-er stillinger) from industry, public sector (including cultural industries), research institutes, health sector, other national universities, abroad.

This indicator captures the reverse relationship of the prior indicator, namely, the number of researchers from the non-academic sector to hold positions into NTNU's academic roster. The rationale for this indicator is that the more research activity is carried out in tandem between external partners from industry and the academic sector, the more likely it is that knowledge transfer and meaningful innovation activity takes place between academia and business. The data source for this indicator emanate from an institutional questionnaire and potential NIFU data, its level are to be aggregated to the institutional and potentially also on the faculty level. The computation will occur on the basis of surveying the number of Adjunct research Positions from non-academic sector divided by the total number of full-time faculty.

7. Work-Life Collaboration in BA and MA theses with private sector (including creative/cultural industries), public sector (excluding health), health sector

This indicator captures the number of student projects (thesis projects or freelance projects) that are co-developed with industrial partners and are aimed towards capturing externally- driven activity on the subject from students. The rationale underpinning this indicator is that projects that are co-developed with industry may have higher probability of exerting regional impact and improving the chances of student employability, financial consequence, and measurable innovation. The data source for this indicator emanate from an institutional questionnaire and its level are to be aggregated to the institutional and potentially also on the faculty level. The computation will be based on tracking the number of work-life collaboration in BA and MA thesis divided by the total number of thesis.

8. Approved agreements/Memoranda of Understanding with social actors (e.g. DNB, municipalities, etc.).

This indicator captures another underexplored dimension of innovation, namely the number of Approved agreements/Memoranda of Understanding with social actors (e.g. DNB, municipalities. Its main definition is based on identifying the five most important approved agreements with social actors (in terms of size or income potential). The rationale for this indicator postulates that the number of approved agreements and MoUs is a reflection of the dynamic synergy between funding and people towards realizing knowledge transfer links of the academic community to the broader society. The data source for this indicator emanate from an institutional questionnaire and its level are to be aggregated to the institutional and potentially also on the faculty level. The computation will be based on tracking the number of approved agreements and/or MoUs.

9. Co-participation in R&D projects per sector. Number of companies and public sector organizations which are involved in these activities.

This indicator captures a well-explored of applied innovation, namely the co-participation in R&D projects per sector in juxtaposition with the number of companies which are involved in these activities. The rationale underpinning this indicator postulates that the number R&D co-participation is a reflection of the dynamic synergy between funding and people towards realizing knowledge transfer links of the academic community to the industrial sector. The data for this indicator will emanate from an institutional questionnaire and clustered on the the institutional and potentially also on the faculty level. The computation will be a survey of the co-participation in R&D projects per sector as well as a descriptive survey of the number of companies which are involved in these activities.

10. Open knowledge transfer - number of "open source" licenses

This indicator also captures an emergent aspect of innovation on the crossroads between networking and commercialization, namely, the open knowledge transfer and the correlated number of licenses. The rationale for this indicator hinges on the assumption that open knowledge sharing here involves open research and knowledge sharing of results created by employees at NTNU, and constitutes an important contribution to open innovation from the UoH sector. As an indicator, only sharing of results / intellectual property explicitly subject to a license is included. NTNU's policy for intellectual property rights provides guidance and definitions. Examples of typical licensing mechanisms are open- source code sharing or Creative Commons licenses. And, as a further specification, publications and articles are not included as these are included as an indicator of research results. The data source for this indicator emanates from an institutional questionnaire and potential Cristin Data. The data level is to be aggregated to the institutional and potentially also on the faculty level. This indicator will be computed based on the number of licenses to industry-based actors as open sources.

11. Indicators for commercialization and student-based entrepreneurship

In addition, we suggest five additional commercialization indicators:

a) Number of university-student start-ups
b) Number of academic start-ups (based on members of faculty)
c) Number of innovation ideas submitted to the local Technology Transfer Office (DOFIs)
d) Number of commercial licenses
e) Number of filed priority patent applications

Indicators that have been considered, produced but discarded from the “canon” of HEI innovation indicators

Indicators that have been considered, produced but discarded from the "canon" of HEI innovation indicators

The following indicators have been produced in the pilot project but due to comments from the departments´ faculty and from the plenum discussions on the cost-benefit trade-offs we decided that either they were too costly or not important enough or not well-defined to be included in the set of future innovation indicators in their present form.

Number of Stud-ENT Applications (As proxy of innovation indicator for student-based innovation and entrepreneurship)

This indicator captures an underexplored dimension of innovation, namely the degree of student entrepreneurship as reflected to the total amount of Stud-ENT Applications from students. The rationale underpinning this indicator is that the student-led applications projects that are submitted can provide meaningful insight into the competitiveness and innovation extroversion necessary for establishing new entrepreneurial links. The 14 departments have reported a very low number of such applications (one in 2020). This renders this indicator as less reliable and valid than what we thought in the beginning of the pilot project.

Innovation-oriented conferences (Business days, technology events, hackathlons etc.)

This indicator captures the dimension of networking, namely, the number of conferences and their akin number of participants. The rationale that grounds this indicator is that the levels of creative interaction between people and funding resources towards a common innovation goal can yield meaningful benchmarks regarding the innovation activity of an academic ecosystem and their probability of forming broader collaborations for non-purely scientific events. Specifically, The number of non-purely scientific conferences (number of events and number of participants). List of the five most important events in which the unit is involved. Here we are talking about non-purely scientific conferences / events (and, if possible, with the number of participants) involving non-academic actors. It is interesting to also estimate the unit's costs associated with organizing / co-financing these events. The data source for this indicator emanate from an institutional questionnaire and its level are to be aggregated to the institutional and potentially also on the faculty level.

Number of events and number of participants in university events – Concerts, exhibitions, book-opening events etc.

Like its akin prior, this indicator also captures the dimension of networking, and particularly the number of events and their akin number of participants in these university events which are do not qualify as conferences (i.e. concerts, exhibitions, career days, etc). The rationale that grounds this indicator is that the levels of creative interaction between people and funding resources in events outside the scientific sphere strictly defined can yield meaningful benchmarks regarding the innovation activity of an academic ecosystem and their probability of forming broader collaborations for non-purely scientific events. The data source for this indicator could potentially be the Cristin Data in the future. But for now, this indicator seems not to be considered important enough.

Number of health innovations

This indicator also captures an emergent aspect of innovation on the crossroads between networking and commercialization, namely, the number of *health service innovations*. The rationale for this indicator postulates that the number of health innovations presents a reflection of the broader synergies of academia, industry, and society. The data source for this indicator we thought emanated from Helseforetakenes database on health innovation in Norway. The database in its currently format does not however report collaboration with HEIs and hence it is not possible to report these data for NTNU. This indicator will be possible to measure properly as NTNU-contributions to registered numbers of health innovations in the future, given that this information is recorded in the future.

Other possible explorative innovation indicators to explore in the future

Below there is also a list of alternative, novel, and even more explorative innovation indicators which, upon deliberation, could be rendered useful for data collection and data analyses for the purposes of this project, but – taken together - with a considerable cost.

a) Lectures, Courses, and Presentations in Industrial Settings
b) Guest Presentations from Industry on courses
c) Several measures on Joint Labs and jointly-used spaces, co-funded by universities and companies
d) Tailor-Made teaching programs for companies or government agencies (and certifications) in addition to ordinary life-long learning activities (EVU).

Final remarks – part 1

In the wake of the last 30 years, the relationship between universities and businesses has been irrevocably transformed and now it is increasingly common to conceive HEI campuses as *innovation eco-systems*. Some of them with a strong presence and extensive regional, national and even global reach, others less systematically architectured and with more limited outreach. Facing an accelerated pace and complexity of innovation, companies and universities can no longer rely on their internal R&D processes alone. This enhanced complexity has given rise to the need to peruse, identify, and absorb externally sourced relevant knowledge in a wide variety of disciplinary areas, sectors and institutions. By virtue of their nature, universities are gatekeepers to the scanning of new knowledge frontiers and the early identification of the next generation of technologies, fostering networks with a complex and constantly changing give-and-take of ideas, cultural meaning, knowledge, IP, and market opportunities. Not only are values, interactions, and roles of universities, firms, and government revisited, but these changes are accompanied by a common focus on the new forms of connectivity that can mobilize innovative potential. Henceforth, NTNU's role in this growing innovation ecosystem may span beyond the traditional commercialisation indicators and capture new and promising dimensions of its broader innovation contributions. We hope and we believe that with this report presenting a set of 15 indicators that attempt to capture different aspects of innovation contributions and activities, we contributed to bring the discussion of measuring innovation from HEIs a step further, acknowledging that there is a more work to do in the future in four specific domains:

- Evaluate the importance, quality and cost of the suggested indicators
- Standardize the collection of information for these indicators in a manner that is cost effective for the departments and if possible relying only on the extant administrative databases
- Evaluate the added value of these indicators compared to extant indicators on research and education for the innovation governance of HEIs.
- Conduct more research (quantitative and qualitative) in order to understand inner dynamics and interconnections between the suggested indicators at the department and HEI levels.

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Part II
Summary of the more detailed reporting on the collected indicators

Summary of the more detailed reporting on the collected indicators

This chapter presents a brief summary of a lengthier report written in Norwegian for internal purposes within NTNU and for circulation in Norwegian decision-making circles. We redirect the interested reader to this unabridged Norwegian report for details on findings and analysis of the specific indicators.

Recommendations

One of the first recommendations we would like to make regarding measuring the future indicator set of innovation contributions at NTNU (and possibly for national HEIs) is a question of method for measuring innovation performance, namely, the process of identifying key performance indicators and normalization factors which may benchmark the innovation work at specific departments (institutter) and across the institution. To be sure, this effort to standardization is not to be confused with static oversimplification and reductionism of the innovation process as linear. Rather, it should be an attempt to enter and understand the iterative process of interplay between factors of quantification and, conversely, nuancing and triggering for deeper quantitative and qualitative exploration of emerging performance indicators.

In a similar train of thought with this question of method for *broader innovation performance*, a second recommendation for further work on innovation indicators would be the establishment of methodological protocols for each specific indicator, with a renewed and commonly agreed description of the data definition for each indicator, its significance, potential for automatic generation of data, its reliability, data quality standards, and its normalization standards. In that way, each indicator could be more critically reexamined and gain further depth and replicability across institutes and, eventually, institutions.

Third, one of the prospects for the amelioration of this set of innovation indicators, would be the further development and tailoring of existing data sources (from central administration/economy/HR and NTNU´s TTO). In that way, each data source would gradually gain lower costs, greater transparency, and ease of processing, for current and future data collection. In parallel, a recommendation for the development of data collection would be the assignment of the curation for the local data collection by a newly appointed advisor who would be precisely mandated to curate this kind of data, both with regards to the range and the detail of resource-intensive datasets (such as e.g., human capital monitoring and networking activities). This kind of advisor/ data curator would report centrally to an institution and allow also potentially for the surfacing of further connections between datasets.

As a further corollary of this data set curation, a potential role for ameliorating the innovation indicators would be the strengthening and consolidation of existing data sources through information campaigning and explicit information requirements from all institutional members. A focus on information collection such as the registering additional professional activities (sidegjøremål), the establishment of collaboration agreements of master students with industry, the establishment of registered collaborations for BA thesis writing, as well as the data collection about the labor market placement of PhD students are all potential candidates for consolidating data collection and vital strategic information flow for NTNU. Moreover, the development of a newly-minted central data collection solutions could significantly expedite the processing and communication of such innovation data.

Last, but not least, the eventual identification of emergent indicators for notions that progressively gain prominence in the landscape of innovation in higher education, such as interdisciplinarity or sustainability, could be promising avenues for the establishment of further pioneering work with innovation indicators.

Part III
Report on Centers for Research-Based Innovation for Innovation (SFI)

– an analysis of 14 selected annual reports on contributions to Innovation

Report on Centers for Research-Based Innovation for Innovation (SFI) – an analysis of 14 selected annual reports on contributions to Innovation

In recent decades, a wide host of peer-reviewed scholarly inquiry has put the topic of University-Industry Collaborations (henceforth UICs) under the microscope (Ankrah and Al-Tabbaa, 2015; Link et al., 2015; Meng et al., 2019, Roncancio-Marin et al. 2022). UICs´ history has been long and spanning across several decades, while their dynamics have been examined from a multitude of perspectives, with divergent units of analysis, and research methods (for a useful review, see Kaloudis et al. 2019 and Roncancio-Marin et al. 2022). Recently, however, the collaborations between university and industry have been intensified worldwide, and particularly in the US, Singapore, and Europe (Gertner et al. 2011; Kaloudis et al. 2019). The reasons for this intense collaboration have been mutual across universities and industry alike. On the one hand, industry has been subject to several business model disruptions, shorter product life cycles, and faster-paced technological change that requires constant vigilance for staying at the forefront of competition. On the other hand, universities have been subject to significant changes in their funding sources and in societal expectations for more relevance of their research and education activities. Moreover, universities have been progressively seen more as engines of economic growth for regions, creating additional pressure to prioritize their promotion of human capital and successful knowledge exchange. Consequently, the urgency of collaboration between sectors (and ideally the proposition of moving from knowledge exchange to knowledge co-creation) has never been greater. Centrally, governments progressively encourage further the creation of such collaborations, as a way of enhancing wealth creation and general prosperity for the population. However, it is not only necessity that fuels these collaborations. Rather, due to factors such as reciprocal benefits. Industry gains access to elite human capital and, conversely, universities provide to their graduates and faculty staff members a better understanding of the current market, while they learn and test ideas in practice. Universities also gain public legitimacy, since they remain relevant and gain access to different sectoral innovation eco-systems.

Within this broader UIC collaboration background, one of the problems which has recently garnered a lot of attention is how to measure and report innovation results in university-industry collaborations (Alexander et al. 2020; Arvanitis et al. 2008; Atta-Owusu et al. 2021; Cheng et al. 2020; Tseng et al. 2020; Garcia et al. 2020; OECD 215; OECD 2021; Perkman et al. 2013). Reporting these innovations run the entire gamut from intuitive visions of what innovation results looked like to carefully scrutinized analyses. In fact, higher education reporting has so far been practiced though multiple approaches, such as social reporting (Del Sordo et al. 2016; Moggi 2019), intellectual capital reporting (Leitner 2004; Nicolo et al. 2020; Paloma Sanchez et al. 2009), sustainability reporting (Gamage and Sciulli 2017; Talebzadehhosseini et el. 2021, and more recently integrated reporting (Adams 2018; Brusca et al. 2018).

Recognizing the importance of UICs networks and channels, the Norwegian government has since at least the 90-ies established a number of policy measures to forge and boost UIC in the Norwegian research and innovation system (Kaloudis et al. 2019, Chapter 2). The Norwegian Centers for Research-based innovation (SFIs) is arguably the most important measure targeting the development and maintenance of UICs in Norway.

More specifically, the Centres for Research-based Innovation are to develop expertise in fields of importance for innovation and value creation in the Norwegian innovation system. The purpose is to fund long-term research in close collaboration between research-performing companies and research groups. The purpose of the SFI centres are in particular designed to enhance technology transfer, internationalization and researcher training while maintaining and building on research must of high international standards. The SFI centres may receive support for a total of eight years (an initial five-year period with the possibility of a three-year extension). For the NTNU, participation in SFIs is of major significance and volume – SFI represent a considerable share of innovation-oriented external funding - and is considered as one of the most crucial channels of NTNUs innovation outreach. This is the reason why there is a considerable attention from the NTNU leadership on the results and innovation outcomes stemming from SFIs where the NTNU plays a leading or a significant role.

This part of the report has therefore as a goal to gain insight in how the Norwegian Centers for Research-based innovation (SFIs) themselves report on different aspects of innovation activities.

Table 3.1: The objectives of the SFI: Fourth generation. Source: RCN, 2021.

Purpose

A research centre is a dedicated, long-term initiative designed to strengthen and further develop elite, creative research and innovation groups or to build up research groups in strategically important areas.

The overall objective of the Centres for Research-based Innovation (SFI) scheme is to enhance the ability of the business sector to innovate and create value through a greater focus on long-term research.

The SFI scheme seeks to:

- Facilitate active, long-term cooperation between innovation-oriented, R&D-performing companies and prominent research groups.
- Promote the development of outstanding industry-oriented research clusters that are an integral part of dynamic international networks and that enhance the internationalization of the Norwegian business sector.
- Encourage and enhance researcher training and the transfer of knowledge and technology in areas with major potential for future value creation.

The SFI scheme is characterised by broader objectives, a longer-term perspective and a more targeted focus than other innovation-related instruments administered by the Research Council. The scheme provides the R&D-performing component of the Norwegian business sector with the opportunity to take a longer-term perspective, enhance continuity and reduce risk in their research initiatives.

For the research groups, the scheme makes it possible to achieve long-term development of expertise through research of high international calibre conducted in close cooperation with companies. The scheme is also intended to enhance quality and efficiency in the public sector.

When selecting centres for SFI status and funding, importance will be attached to their potential to generate innovation, business development and sustainable value creation within the centre's thematic priority areas. The scientific merit of the research must be of high international calibre.

Table 1 "The Objectives of the SFI: Fourth Generation": RCN 2021

Rationale of annual report analyses

Over the span of several decades (Thomas 1973), annual reports have been repeatedly studied as a source of information for the management and disclosure of human capital (Brennan 2001), strategy disclosure (Santema and van de Rijt 2001), corporate responsibility (Waller and Lanis 2009), stakeholder analysis (Kent and Zucker 2017), but also broader organizational identities (Ditlevsen 2012) and mythmaking (David 2001). At the core of such analyses of annual reports often inheres the deep predicament of what researchers often term "voluntary disclosure" (Abeywardana and Panditharathna 2016): how much can an organization share openly regarding its strategy, its prospects, but also its challenges? Despite the hefty attention that annual reports have garnered in the industrial sector, their import, impact, and citation in the tertiary education sector has been minimal and fragmentary (Coy et al. 1993; Guan and Noronha 2013), whereas systematic synthesis or analysis of annual report data from such data sources has been completely absent. This study seeks to study more deeply this dilemma of "voluntary disclosure" in a particular epiphenomenon of academic innovation which has never been previously documented, namely, the annual reports of SFIs. Our primary hypothesis and early empirical findings indicated that the annual reports offer a plethora of insights into the potential innovation practices that occur in SFIs, and at the crossroads between academia and industry. On the one hand, they do require some hard facts, such as personnel, accounts, and publications, which veer to just pure accounting, without any need for further explanation. On the other hand, the annual reports allow for a lot of room for observing how SFIs translate these research activities into innovations, since the amount of detail in disclosure is discretionary on length (no specific page requirements) and bound by the following eight NFR guidelines: summary, vision/objectives, Research plan/strategy, organisation (organisational structure, partners, cooperation between the centre's partners), scientific activities and results, international cooperation, recruitment, and communication and dissemination activities.[4] Consequently, the key objective of this section was to document and evaluate -from an empirical standpoint- how SFIs disclose their innovation results and general innovation strategy within these empirical bounds. Ultimately, such an inquiry will shed more light into the aspects of innovation awareness and the different innovation priorities that undergird these centers.

[4] https://www.forskningsradet.no/nar-du-har-fatt-finansiering/prosjektrapportering/rapportering-for-sentre/

Table 3.2: Reporting Template of SFI: Fourth Generation. Source: RCN 2021.

Reporting Template

The annual report is to describe the status of the centre's activities, and should contain the following items:

- Summary
- Vision/objectives
- Research plan/strategy
- Organisation
  - Organisational structure
  - Partners
  - Cooperation between the centre's partners
- Scientific activities and results
- International cooperation
- Recruitment
- Communication and dissemination activities

Attachment in the report (see attached form):

- Personnel
- Accounts
- Publications

Methodology

We follow the methodological approach of a qualitative design and the research protocol of content analysis method (Bowen 2009; Bryman 2016; Gray et al. 2007; Gioia et al. 2013). Similar to other forms of qualitative design, the protocol of content analysis sought to systematize the empirical material, interpret it, and yield meaningful findings to the research question being posed, as well as elicit meaning and depth to the question, namely, that of reporting SFI innovation results in their annual reports (Creswell and Poth 2018).

Based on the analysis and parameters of the general pilot study for innovation indicators (see part 1 and 2 in this report), in this part of the report we set out to examine how SFIs present their contributions on the four analytical dimensions for parsing innovation: additionality, people and worklife, networks, and commercialization.

Sample Choice

The selected centers for this study have all been from the research of NTNU. The choice has been made based upon three factors. First, NTNU has been involved in the majority of these initiatives, making it a very representative university for the purposes of this analysis. Second, NTNU has some schemes of central governance regarding innovation (Vice-Rector for Innovation, Innovation Leader faculty positions-Innovation Managers), which could be arguably evincing a broader strategy and coherence regarding the use of innovation. Finally, NTNU has been, to the best of our knowledge, the only Norwegian HEI which has the largest inventory of innovation-specific resources centrally (NTNU Discovery, NTNU Student Innovation, NTNU TTO), making it the ideal case study for understanding the broader ecosystem of innovation within the university, which spans across centers.

This study included 14 Annual Reports for the year 2020 from 14 SFIs (Centers for Research-Based Innovation). In further detail, our data comes from the annual reports (2020) of 14 SFIs (SFI "Centre for Geophysical Forecasting", SFI CIRFA – Centre for Integrated Remote Sensing and Forecasting for Arctic Operations, CIUS Center for Innovation Ultrasound Solutions,, SFI NorwAI, SFI iCSI (industrial Catalysis Science and Innovation), SFI Klima 2050, SFI Metal Production, SFI NORCICS, SFI Blues, SFI Harvest, SFI Move, SFI Sirius, SFI Smart Maritime, SFI Subsea Production and Processing) where NTNU is the main partner or a key collaborator.

These documents were collected in order to capture the "best practices" of innovation reporting and akin correspondence with our four analytic dimensions for innovation. A set of terms was used when mining these documents (*innovat* (301 counts); *value (107 counts); *student (133 counts); *system (617 counts); partners* (581 counts); *process* (491 counts); *impact (126 counts); *dynamic (223 counts); spin* (38 counts); *pilot (42 count); *intellectual property (5 counts); IPR (9 counts); *gender (4 counts) *creation (16 counts); * knowledge transfer (4 counts), * organization or organization (57 counts), *collaboration (159 counts), *dynamic (223 times), *synerg* (13 counts); *network* (69 counts), *conference* (226 counts) , * event* (26 counts), *open access (1 count), *open source (26 counts); *license (12 counts)*; *funding (56 counts); Horizon Europe (4 counts); LinkedIn (16 counts); Twitter (6 counts)). This list of keywords was informed by latest published research on UIC, the terms within the SFI call itself, SFI´s own midterm evaluation of the scheme, and the independent audit conducted by Damvad analytics (Damvad Analytics 2018).

Data Analysis

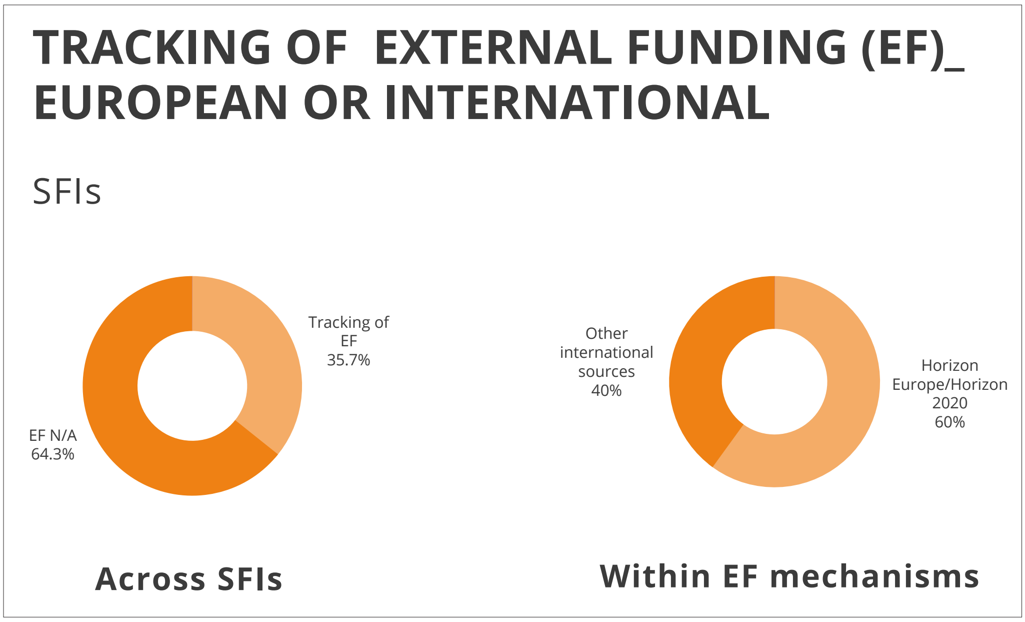
The document analysis approach was undertaken in accordance with established methodological protocols, and it combines elements of content analysis and thematic analysis (Bowen 2009; Bryman 2016). Content analysis in the context of document analysis refers to the research process of identifying and collating meaningful sections of the document text, such as innovation results checklists, innovation outcomes figures. Conversely, thematic analysis was used in order to examine how patterns within and between the documents as key themes emerge. Such qualitative analysis combines both these analytical approaches, in order to reap the benefits of the rich breadth of content contained within these documents, as well as employing a structured approach to managing and organizing the data around key topics (Nowell et al. 2017).

The keyword results akin to innovation were entered into a Microsoft Excel Spreadsheet, to enable a systematic examination of the data according to emergent categories. The annual reports were examined in their original format (separate online PDF) and were subsequently merged into a comprehensive large-file PDF (spanning 656 pages, excluding annexes), in order to allow for the systematic examination of data across SFIs. Throughout the analysis, a log containing raw notes and emergent data was frequently updated. Color-specific codes were highlighted throughout the documents to illustrate pertinent points. The codes were iteratively examined, and emergent patterns were labelled as potential themes for further rumination. Data saturation was achieved when the scrutiny of all the SFI annual reports and the examination of in-text references ceased to yield new themes or content (Morse 1995). The themes and patterns that supported their emergence were inspected by a wider study team, and any divergent perspectives were resolved through group discussion.

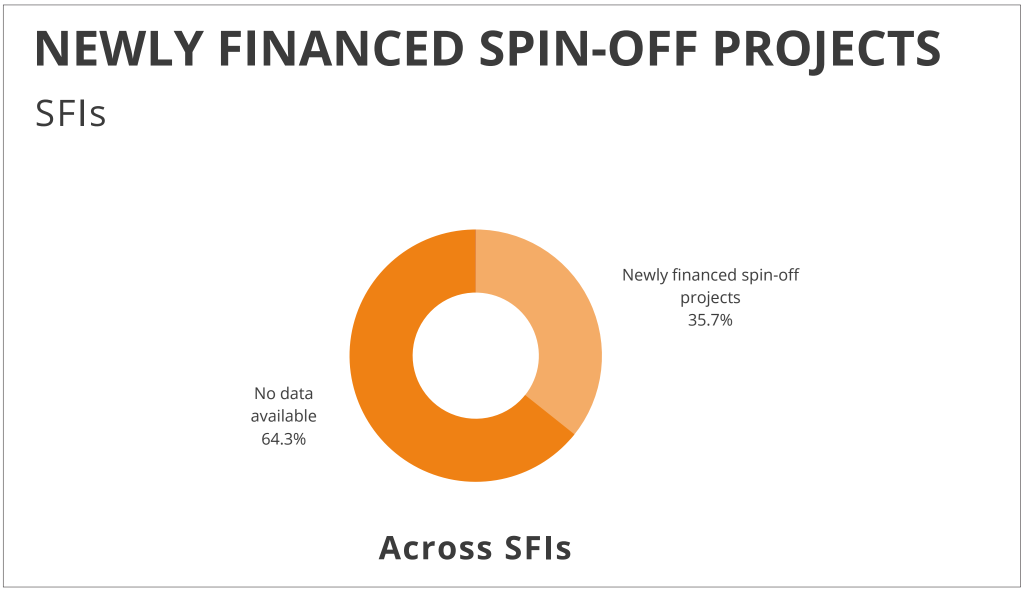
Innovation Dimension 1: Economic Indicators

One of the most persistent and well-established elements of innovation is the economic performance (understood here as the ability to attract additional external funding, i.e., additionality) of a research endeavor, and particularly that of an SFI, which is an established variant of a research center of excellence. After scrutiny of the annual report data (2020), we have come across two principal findings. The first is about the economic attractiveness of these innovation centers, as established through their ability to track and report on research funding.

From our sample, only one third of the centers tracks and reports on external financing from international sources (such as EU or other global opportunities). This is a finding which aligns also with the independent evaluation from the Damvad report on the lacking efforts of several SFIs to attract or align themselves for European funding. Within this minority of centers, moreover, an additional finding has been that only 60% of these sources seeks for funding opportunities from the Horizon mechanism. This finding is rather understandable given the formal agreement with the RCN and its parameters of formal contractual obligations, yet telling with regards to the general positioning of these centers within the European landscape, which should generally be conducive to more European-targeted resources.



Despite the seemingly low interest in engaging with external funding, the picture of the future and the ability of these centers to kick-start new projects and attract other types of funding is rather flourishing. Described with terms such as "pilot projects", "associated projects from 2021", "new projects/spin-off projects", 5 of these centers have reported either completely new or recently started projects that emanate directly from the collaboration with industry or other research and industrial partners. This is a rather encouraging finding about the ability to networks to come together, collaborate, and generate attractive research. And, ultimately, this attractiveness constitutes an encouraging positive trend in the workings of SFIs and their scheme, which can further stimulate innovation collaboration between university and industry.



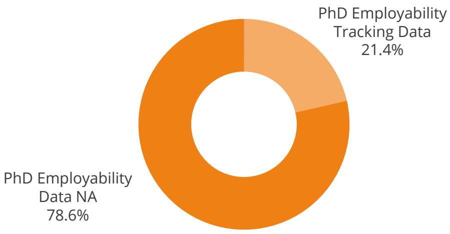
Innovation Dimension 2: People and Work life

In the second aspect of our innovation analysis, we have concentrated on the abilities of these research centers to track their human capital, and its success in finding their way to the academic or non-academic job market. In light of growing discontents about the role and function of PhDs in academia (Cyranoski et al. 2011; Germain-Alamartine et al. 2020; Germain-Alamartine and Moghadam-Saman 2020; Iversen et al. 2021; Janger et al. 2019; Sauermann and Roach 2016;), this is an important indicator for establishing trust in the sector and the transferability of knowledge to society (know-how, know-what and know-whom). However, the findings from these reports are rather alarming: only a small minority (20%) of these centers actively tracks the PhD employability of their candidates, which in itself is a low figure in light of the developments for accountability in the sector. Moreover, this finding is compounded by the fact that two thirds of these tracked people do actually attain non-academic employment, which shows the importance of keeping track of this employability metrics.

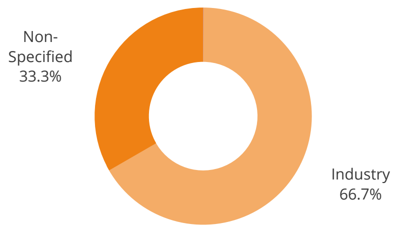
Further in line with the tracking of human capital, one dimension that has received even scantier attention is the role and activation of MA students in the knowledge transfer in society, as well as the students´ potential job prospects. Only the minority of SFIs still make explicit mention of their MA students' contributions, and from this minority, only half make specific mentions of jobs or internships for MA students. In light of growing emphasis on student entrepreneurship and attractiveness to the job market, this is a rather striking finding which merits attention and leaves room for growth with regards to integrating the prospects of research-based innovation not only in the academic, but also in the industrial sector.

JOB PLACEMENT OF PHD GRADUATES

SFIs



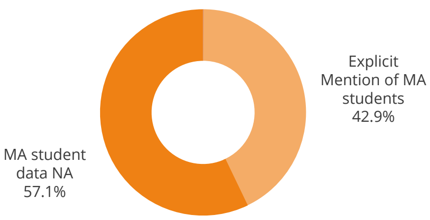
Across SFIs



Employability in the Non-Academic Sector

INVOLVEMENT OF MASTERS STUDENTS

SFIs



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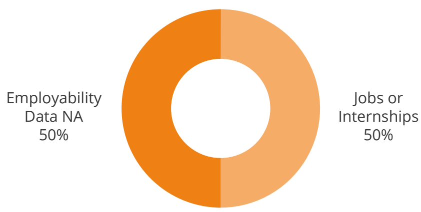
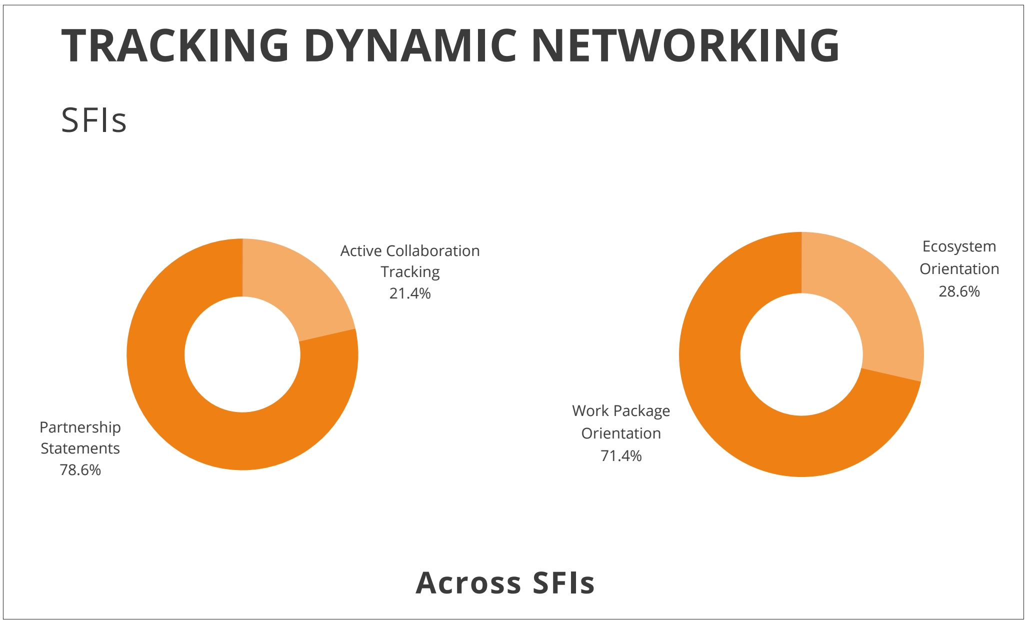


Employment Prospects of Masters Students

Innovation dimension 3: Networks

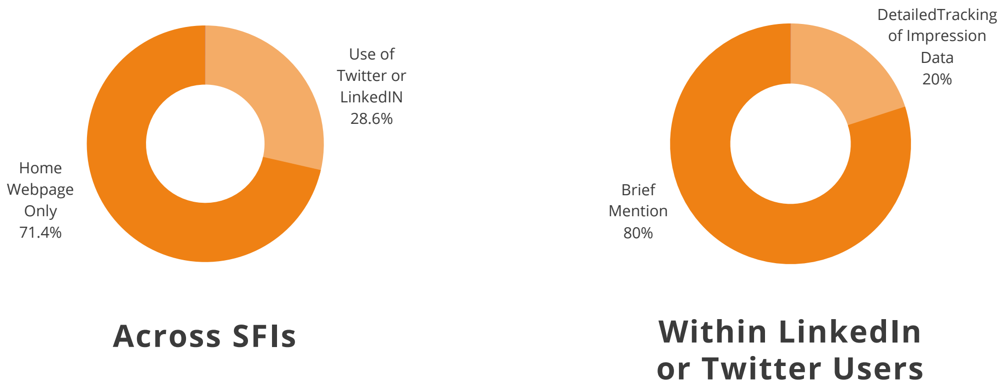
Regarding now the third innovation dimension, namely, the importance of formal networks and dissemination for the SFIs, the data reveal interesting patterns. On the one hand, all SFIs display lengthy descriptions of their internationalization and networking activities, particularly also with regards to their formal agreements with industry. However, only a fourth of the SFIs in our sample move beyond mere mention of partnerships and actually describe the dynamics of their networking activities (how partners enter or exit, how partnerships grow) as well as their deliberation and decision-making practices. This is an important finding, since such a pattern would reveal not only formal agreements, but the very dynamics of these collaboration, and how these dynamics beget new knowledge (Costa et al. 2021; Drejer and Jørgensen 2005; Guerrero and Urbano 2021; Hohberger et al. 2015; Kaloudis et al. 2019; Köhler and Sönnichsen 2022). Moreover, this lack of dynamic descriptions is further revealed in the lacking orientation of knowledge creation in the ecosystem way of thinking, which allows for more spontaneous or serendipitous connections between partners, rather than the a priori assignment of work packages and strict divisions of labor.

A second finding in the data which calls for our attention is the modes of dissemination and communication through social media channels, which go beyond an SFI´s individual website (such as Twitter and LinkedIn). The data reveal a lacking interest in engaging with external, well-established platforms, which could raise, in turn, questions about the scope and international orientation of both recruitment and dissemination of research results. In addition, the detailed - and quantitatively-minded- tracking of impression data is rather rare in the SFIs under scrutiny, which potentially impedes the broader understanding of networking dynamics and dissemination in these centers.



DISSEMINATION THROUGH LINKEDIN OR TWITTER

SFIs

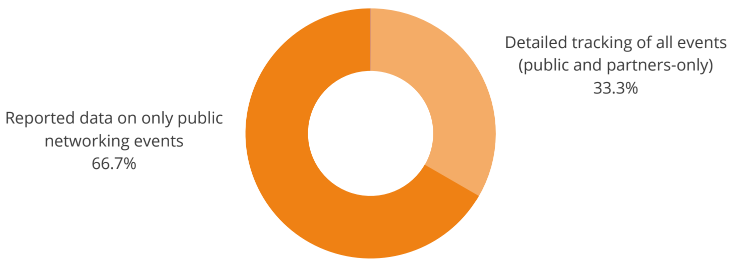


Finally, as a measure of their abilities to form networks, all SFIs *present a very large amount of total bulk of conferences and scientific arrangements* they have participated in (amounting to a total of ca.150), depending on the ways of counting these participations (presentations from the centers, presentations tangentially related to the centers, posters and posters tangentially related), as well as more informal/ semi-formal arrangements (such as “virtual tech lunches”, “common trips”, “networking conferences”, “working groups”, “expert groups”, “workshops”, and “thematic meetings”).

From this large amount of reported arrangements, and despite the ubiquity of the terms “partner” in every SFI report (a total of 430 mentions), only 5 describe in detail their modus operandi for how they track in practice their collaboration with their partners (“invitations to annual meetings”, “adjunct professors for the industry partners”, “reference groups”, “innovation projects_ researchers working with industry partners organizations”) and only one reported perhaps more inconvenient results, such as the departure/withdrawal of some partners (SFI Move). This comparison between arrangements for the public and, conversely, for their more private audience (between partners) can be rather telling with regards to disclosure of new innovation approaches and outcomes. However, the general state of the SFIs ability to report their networking abilities is high and presents on average a lot of detail.

NETWORKING EVENTS

SFIs



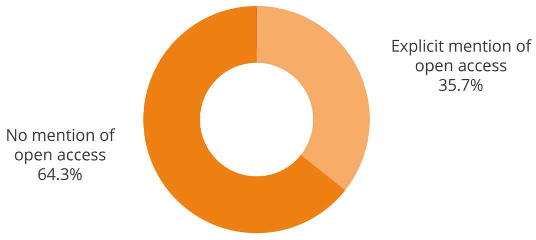
Across SFIs

Ideally, we should capture whether these events are purely scientific or including industry and, even more open lay audiences and public, with the purpose to achieve dissemination and develop the innovation ecosystem of the SFI. Given the variability of quality of the annual reports and the time limitations of this pilot project, in-depth granular analysis of this specific aspect of the networking activities/events was not possible to fully identify.

Further on the front of *open access*, the general issue of open access and open license IP has been a cornerstone in the pursuit of innovation, particularly for research institutes and projects which seek to create connections across societal actors. However, the actual explicit mention or presence of the word open access is limited in the SFIs, with the vast majority (9 out of 14 centers) making no explicit mention of open access in their annual reports. The centers which do use the open access declarations do so either in the form of open databases ("e.g. open source software toolbox", "open drift trajectory model", "open simulation platform initiative", "vessel response tool"), or with strategy declarations ("Open innovation model"). In addition, the more specific pursuit of innovation deliverable, with open license IP has been even strikingly low in the reports, with only one explicit mention of this innovation outcome. This creates some dissonance between the general growing consensus on the importance of pursuing open access in the university sector on all possible fronts and the actual existing practices on the matter. To be sure, our analysis here does not focus on the practice of open access publication, which is only one of the ways that centers pursue openness (and the SFIs do publish on open access with growing rates). Rather, we are talking about other open access tools, platforms, and databases which have direct transferability and operational value for work-life problems and practical challenges. In that respect, the SFI practices still leave much room for growth and open access to all innovation fronts, and particularly the free distribution of software or data.

OPEN ACCESS

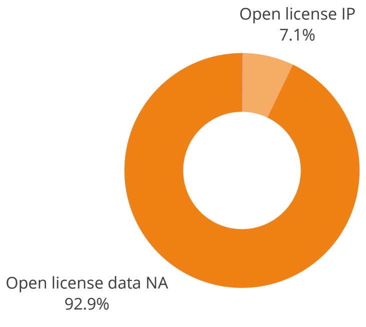
SFIs



Across SFIs

OPEN LICENSE IP

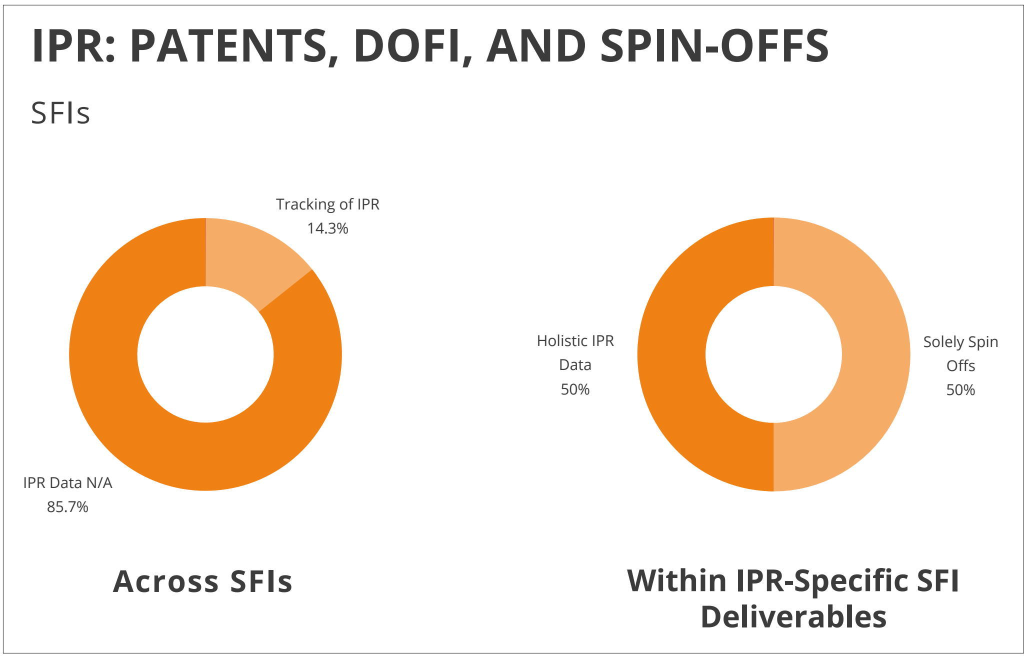
SFIs



Within IPR-Specific SFI Deliverables

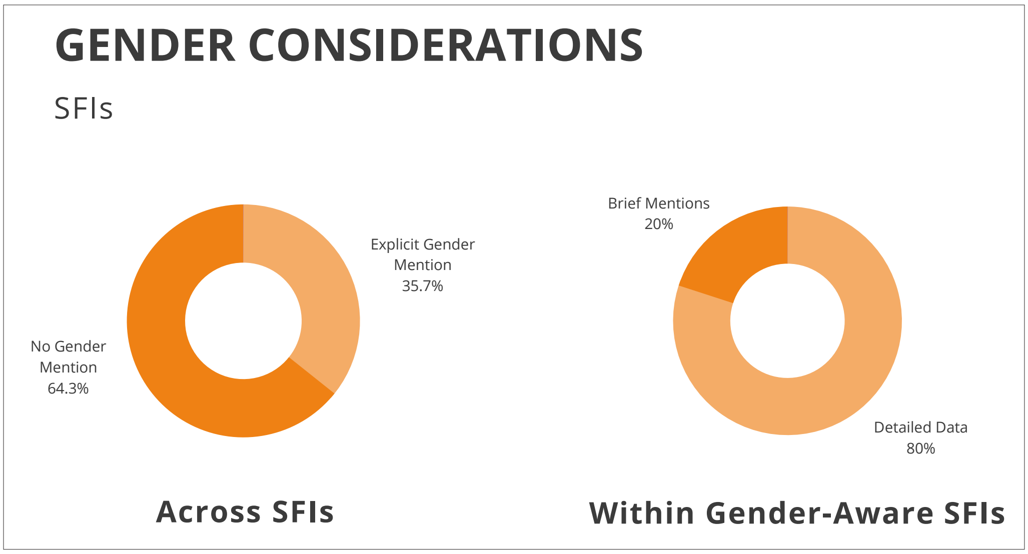
Innovation Dimension 4: Commercialization

Finally, with regards to Innovation Dimension 4 and the topic of commercialization, the data reveal a very low interest (14.3 %) in the tracking of IPR data (patents, licenses, and DOFIs). Moreover, only half of this small minority group makes explicit mention of spin-off ambitions or actions, raising also concerns about the ability of these centers to scale up their efforts and yield revenues for their stakeholders.



Unexplored Innovation Dimensions

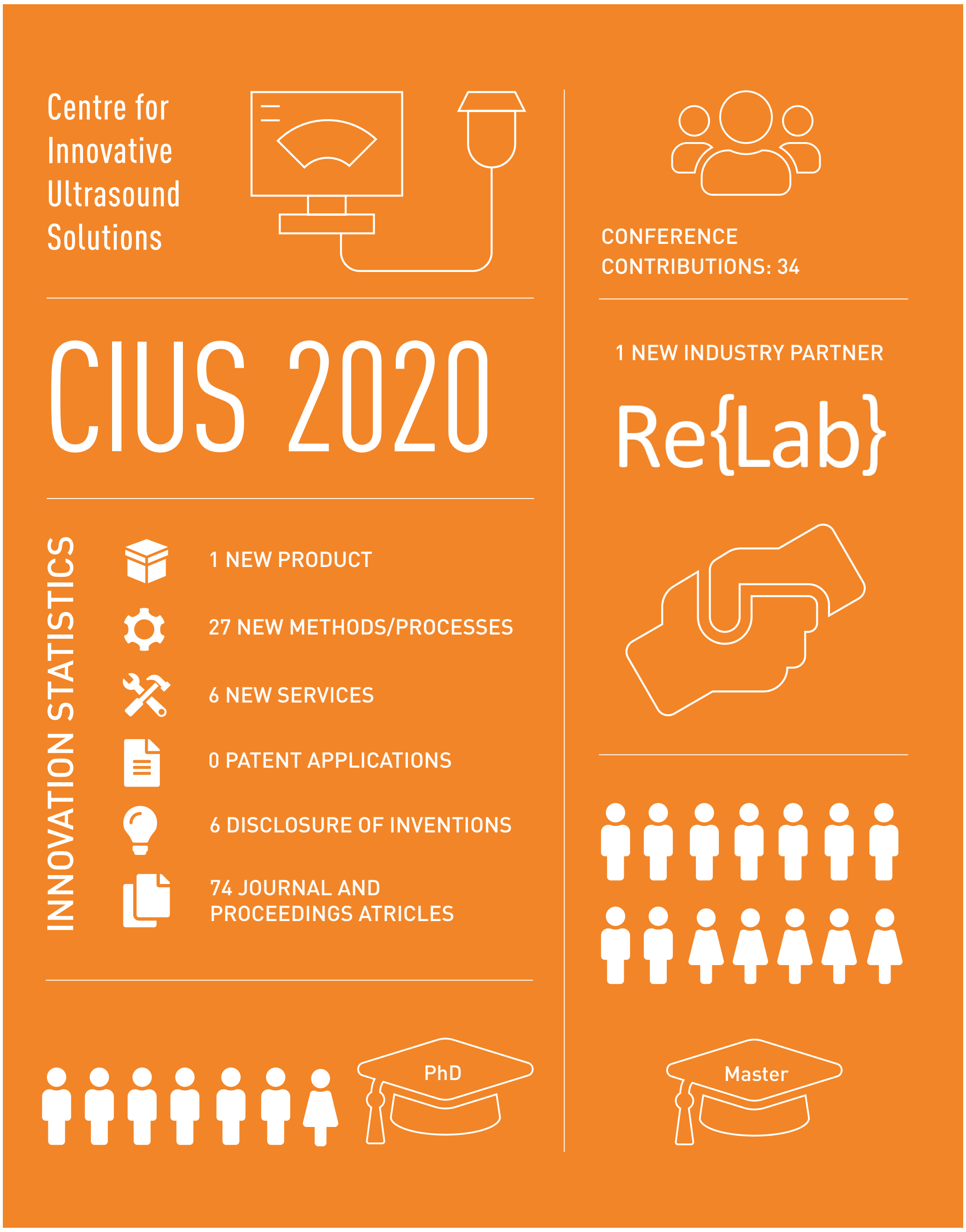
The final set of data comes from more explorative avenues of innovation, namely, public value innovation data. Our focus, commanded from the data available at the annual reports, is on gender tracking and the ways in which these centers engage in making explicit gender dynamics in their research efforts. Alarmingly, the vast majority (64%) of these centers makes no *mention of gender in their reporting*, raising concerns about the implicit, yet persistent, biases that may inhere in the dynamics of these centers. Moreover, some of this gender reporting is also making brief, rather than detailed, mentions of gender dynamics, showing that there is room for improvement even at SFIs where there already exists awareness of gender imbalance, and its ensuing problems for the public value generation that these SFIs propone. In line with a lot of growing research on implicit bias and its role on gender balance and academic welfare in European academia and transnationally (Gvozdanović and Maes 2018; Menter 2020; Pritlove et al. 2019; Timmers et al. 2010), gender is an aspect that should be scrutinized and accounted for in the fostering of an innovation culture amongst SFIs. In that respect, this aspect of innovation leaves much room for growth and future development.



Summary of findings and final reflections

One of the key conclusions that we can draw from analysis of the SFIs is that, as a general trend, the establishment age of an SFI clearly plays a role in the volume and scope of reportability, the quality of reportability, and the readiness of disclosure.

For example, established and mature centers such as CIUS have reached a very high level of reportability, presenting their readers with precise and granular innovation statistics (see figure below). On the other hand, the majority of innovation centers present very little by means of innovation statistics, and in particular with regards to details of commercialization and economics of innovation that occur in each center. Moreover, the dimensions of human capital management, particularly with regards to the labor market placement and market attractiveness of PhD and MA students is not particularly salient in the reportability of these findings. The same finding goes with regards to networking, where the attention to public events, as well as direct participation of partners in meetings is not met with very meticulous reporting, making it hard to give a very clear picture as to whether several of these networking activities are just scientific conferences or events, and whether these events have bearing to a business partner audience or the general public. This is an elemental dimension for the communication potential of an SFI, and the general transferability and translatability of a center´s innovation findings to its end users and, by extension, to the general public as clear and identifiable innovation statistics.



CIUS results (so far)	'17	'18	'19	'20
DOFIs	4	7	7	6
Patent pending	0	1	1	0
Licencing considered or discussed	3	5	3	3
Licence agreements	0	0	0	0
Open Source licences	0	0	0	1

CIUS results (so far). (Row 2) Number of Disclosure of Innovation/inventions (DOFI); (Row 3) Number of patent pending or patent applications; (Row 4) Number of licence considerations or discussions; (Row 5) Number of closed licence agreements; (Row 6) Number of Open Source Licences.

The general impression of innovation at SFIs are positive and definitely merit our attention. The publication rates, the collaboration with industrial partners, as well as the overall ability of SFIs to communicate across sectors and audiences, as well as to generate measurable value, are solid and should not be taken for granted.

However, the reporting of innovation at SFIs leaves occasionally much room for growth. First and foremost, as engines of growth, the SFIs could definitely allow for more reporting and general public information on the additionalities they create, namely, on the new EU/RCN or pilot projects that emanate directly from the establishment of an SFI. This kind of reporting of the positive innovation externalities of an SFI would create a much better sense of accountability and trust in the innovation work that occurs, and the innovation spillovers that such work can generate.

To further corroborate this point, the aspect of commercialization and its measurement or effects on the innovation performance of an SFI are not well-reported. Consequently, the establishment of a baseline of key performance indicators (KPIs) for commercialization, particularly with regards to declaration of new ideas (DOFIs), pending or approved patents, as well as spin-off companies is a key prospect for future reporting of SFIs, which would create healthy benchmarks to strive towards and reflect upon innovation efforts. A third dimension to allow for future improvement of SFI efforts is the more detailed reporting of activities that yield open access (data, codes, digital platforms, software programs, methods, open-source licenses). Open access is a critical dimension, both in terms of adding value to the end users of an innovation, but also for the broader public. This kind of open access knowledge creates major benefits for translating scientific knowledge into practice, making research and international environments more globally competitive, and elevating the reach of knowledge beyond the academic walls.

A fourth dimension for the general improvement of SFIs reporting is the management of human capital, and the way centers engage with the labor market placement of their masters and PhD graduates, to secure the strategic placement of fresh talent and new skills in both industry and academia.

Given the growing dissatisfaction with the market placement of PhDs and the frequent misalignment of skills and work tasks (Cyranoski et al. 2011; Germain-Alamartine et al. 2020; Germain-Alamartine and Moghadam-Saman 2020; Iversen et al. 2021; Janger et al. 2019; Sauermann and Roach 2016;), the careful monitoring of the labor market placement of qualified human capital could mean a great deal both for the credibility of the university as a site of growth, but also for the ability of industry to absorb human capital and put forefront knowledge into practical, occasionally life-altering applications. This is particularly true of a more neglected aspect of the graduate population, namely, the master student graduates, which is a body of the university´s human capital which has not been carefully monitored in terms of career development.[5]

Finally, an aspect of the SFIs which leaves room for development is that of the reportability of values such as gender balance, equal opportunity, and process transparency in the recruitment and practical execution of innovation efforts. The reportability of such considerations and less directly tangible aspects of value creation carry a great deal of weight not only to the results of innovation per se, but also to the general reputational cascades of a university´s ecosystem of values.

5 In the analysis of the 14 NTNU departments, we do not include an indicator on employability of masters graduates since this is an indicator more relevant to measure as a direct educational output and not as a direct innovation output. However, there is no doubt that this is an important indicator to capture at the level of SFI, department within a higher education institution (HEI), and at the level of of HEIs.

Underscoring the prominence of this dimension can allow for greater trust and authority in the university´s role in society, and its ability to put forth examples worth emulating and aspiring towards.

In general, the SFIs do display variability in their reporting of the innovation, and their ability to indicate or signal their innovation efforts, both in terms of innovation outcomes, but also in terms of innovation processes and the underpinning dynamics that innovation is constructed upon. If we were to present our findings by means of an innovation spectrum, at the lower end we may put a more traditional view of academic reporting with emphasis on scientific reporting and research outcomes. This kind of reporting, captured by publication metrics and the emphasis on publication impact, is placing prime value in the ability of a research group to report pathbreaking research and achieve visibility within a field or across research fields. To be sure, this is a key function of an SFI, which is clearly mandated from the NFR to “further develop elite research and innovation groups”.

On the opposite end of the spectrum, we find the prospect of innovation reporting, which places emphasis primarily on the innovation outcomes per se and considers research as the springboard and means of innovation, not the end in itself. In this kind of reporting, the prime emphasis is put on how innovation stems out of a center´s research effort, and how these research efforts have direct applicability in the end user´s, industrial or business partners´, and general public´s everyday practices and working routines. In this fashion, innovation reporting turns the traditional dynamic of academic work on its head and prioritizes real-life applications and hands-on transferability as the cornerstone of innovation, seeking to combine the drive of curiosity with that of practical utility and measurable value creation. And more strikingly, this kind of value creation does not simply encapsulate monetary value. Rather, it captures also more intangible value creation, such as that of social and public values of more normative texture, such as internationalization values, transparency, and open access to information, as well as gender balance considerations.

This kind of reporting across the spectrum of both monetary/commercial and normative values lends innovation reporting with a greater sense of depth which spans beyond commercial trends, fads, or financial gains, to incorporate public values with a long-term and direct social purpose. This reporting can allow for innovation to play a key role in the transformation of a university to an engine of growth, a growth that is both value-centered, long term, and -in the final analysis- sustainable. Ultimately, this outlook of innovation outreach is in direct alignment with the objectives and the findings of the overall pilot project, which targets broader innovation contributions in a university´s ecosystem.

Certainly, no dataset is without trade-off choices and limitations. The innovation indicators offer various insights in terms of cost-benefit analysis for the SFIs, as well as some significant methodological limitations for the kind of evidence that annual reports may represent (since 4 out of the 14 SFIs are very recently established and cannot be expected to provide tantamount levels of detail and granularity of results).

In conclusion, the indicators which have been conceptualized for the evaluation of the main innovation functions across an entire university ecosystem in part 1 of this report are not directly applicable to the structure and functions of an SFI, which follows an organization logic premised on the call administered by the Research Council of Norway. Nonetheless, the four dimensions which underpin the suggested indicators, namely, economic (measured as additionality performance, defined as the ability to attract external funding in addition to the funding from the Research

Council of Norway and the SFIs industrial partners), people and work life, networks, and commercialization remain highly relevant and salient for the structure and innovation functions of an SFI, as well as for the furthering of an innovation culture around innovation reporting from these centers. Consequently, in order to further develop and nuance the reporting on innovation, several ideas are in place. First and foremost, a common discontent also from the published research is the lack of general key performance indicators which can clearly orient researchers or centers about their innovation presence. To be sure, we do not advocate for a linear model of technology readiness level or catch-all terms. However, some preliminary consensus on what constitutes reliable performance indicators are still a desideratum across centers, especially at larger scales of collaboration which entail more interaction volume and- therefore- more complexity. Secondly, the annual and general reporting of each center does not seem to entail any insight into their specific innovation models. The reporting so far allows a great sense of outcome transparency, but little on process transparency, therefore hindering the understanding of the dynamics that underpin deliberation and decisions. Consequently, allowing for some reporting of inner constructive disagreements or fruitful arguments could greatly enhance the process of innovation itself, which is well-established to be the result of the contention with different perspectives. In that area, some input from alumni or from graduate networks could be useful. Finally, the establishment of active dialogue with best practices with other centers could greatly advance the reporting practices for the mutual benefits of the individual SFI and for the funding policy scheme as a whole.

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Annex 1
Complete Version of Recommended Indicators for NTNU in the NTNU-report 2019a

(English and Norwegian Version:
45 Indicators)

A. Indicators for Indirect Contribution

A1. Innovation competence and innovation culture

1. Master students' satisfaction with the educational trajectory's emphasis for innovation.
2. Master students' satisfaction with the educational trajectory's contribution to entrepreneurial skills.
3. Employers' satisfaction with the Master students' ability for innovative thought.
4. Applications/Filings for patents from employees and students at universities.
5. Submitted innovation ideas from employees and students at universities.
6. STUD-ENT applications from the university
7. Applications for internal incentive funds from the university (f.i. NTNU Discovery for NTNU)
8. Number of participations in architectural competitions, business ideas competitions, and other disciplinary competitions.
9. Trademark applications from employees and students at universities.
10. Design applications from employees and students at universities
11. Number of applications to RCN
12. Number of applications to Horizon 2020
13. Number of internal positions with a focus on innovation
14. Study programs and topics/teaching modules with innovation focus (EVU) as well as number of study point credits and students

A2. Collaboration Indicators (Universities' academic core areas)

Project Collaboration

15. Income from innovation-oriented NFR projects (BIA, FORNY etc)
16. Income from participation in Innovasjon-Norge projects (IFU/OFU etc.)
    Collaboration with Industry
17. Number of articles with co-authorship from the business sector
18. Part of Research and Development (FoU) considered as directly relevant from the creation of value in the industrial sector.
19. Research and Development financed from the industry sector as a part of collaborative Research and Development
20. Number of participants as project partners in SKATTEFUNN (Tax Deduction Scheme for Companies with Research and Development Projects).
    Other Collaboration
21. Share of articles with co-authorship with the public sector (hereafter health trusts)
22. Share of articles with co-authorship with research institutes
23. Share of BOA-income as part of total revenues
24. Number of leadership of excellence clusters and excellence centers (SFF, SFI, FME, GCE, Arena, NCE)
25. Number of Participation in excellence clusters and excellence centers (SFF, SFI, FME, GCE, Arena, NCE)

26. Bachelor and master theses in collaboration with external and/or as part of a research project
27. Number of shared positions as a share of faculty positions
28. Number of cooperation agreements (memoranda of understanding) with companies and public enterprises

Mobility and shared Positions

29. University-employed and student participation in public committees
30. Number of Professor II positions financed from external funding sources
31. Number of former PhD students with employment in innovation-participating businesses/enterprises
32. Number of Business-financed PhDs with a sole university as an award-granting institution

B. Indicators for Direct Contribution (results/changes)

B1. Commercialization and business/industry development

33. Initiated licencing contracts from students and employees at the university
34. Registered business establishment from students and employees at the university
35. Registered patents from students and employees at the university
36. Registered trademarks from students and employees at the university
37. Registered designs from students and employees at the university
38. RCN's STUD-ENT awards in a university
39. Reported results regrading business development from SFF, SFI, FME and excellence clusters
40. Reported results regarding business development from other RCN-funded projects
41. Reported results regarding business development from EU-funded projects

B2. Innovation in the public sector and society in general

42. Number of innovations from the health sector in collaboration with the university
43. Prizes and distinctions (for example for good design)
44. Qualitative examples regarding innovation in society initiated by the university
45. Results of the university's artistic development work

Norwegian Version (NTNU-report 2019: 61-63)

A. Indikatorer for indirekte bidrag			
1. Innovasjonskompetanse og innovasjonskultur	**Kilder**	**Nasjonalt sammenlignbar**	**Internasjonalt sammenlignbar**
Master-studenters tilfredshet med utdanningens vektlegging av evne til nyskaping	NIFU/Kandidatundersøkelsene	X	
Master-studenters tilfredshet med utdanningens bidrag til entreprenørskapsevne	NIFU/Kandidatundersøkelsene	X	
Arbeidsgiveres tilfredshet med masterkandidaters evne til nytenkning	NIFU/Arbeidsgiverundersøkelsen	X	
Patentsøknader fra ansatte og studenter ved universitetet	DBH/TTO/FORNY/SPARK/ES	X	X
Mottatte innovasjonsideer fra studenter og ansatte ved universitetet	DBH/TTO/FORNY/SPARK/ES	X	X
STUD-ENT-søknader fra universitetet	FORNY	X	
Søknader til interne incentivmid-ler ved universitetet (eks NTNU Discovery for NTNU)	Det enkelte universitet (For NTNU: NTNU Discovery/ Innovasjonsstipend etc)	(X)	
Antall deltakelser i arkitekt-konkurranser, forretningside-konkurranser og andre faglige konkurranser	Norske arkitekters landsf./andre kilder	(X)	
Varemerkesøknader fra ansatte og studenter ved universitetet	Patentstyret	X	X
Designsøknader fra ansatte og studenter ved universitetet	Patentstyret	X	X
Antall søknader til innovasjons-rettede NFR-prosjekter	NFR	X	
Antall søknader til Horisont 2020	Ecorda	X	
Antall interne stillinger med innovasjonsfokus	Det enkelte universitet	(X)	
Studieprogrammer og -emner med innovasjonsfokus (inkl EVU) antall studiepoeng og kandidater	Det enkelte universitet	(X)	

2. Samspillsindikatorer (universiteters faglige kjerneområder)	Kilde	Nasjonalt sammen-liknbar	Internasjonalt sammenlikn-bar
Prosjektsamarbeid			
Inntekter fra innovasjonsrettede NFR-prosjekter (BIA, FORNY mv.)	Det enkelte universitet / NFR	X	
Inntekter fra deltakelse i Innovasjon Norge-prosjekter (IFU/OFU/ mv.)	Det enkelte universitet /IN	X	
Inntekter fra Horisont 2020	ECORDA	X	X
Samarbeid med næringsliv			
Andel artikler med samforfatterskap med næringsliv	Christin/NIFU	X	X
Andel FoU vurdert som direkte relevant for verdiskaping i næringslivet	NIFU/FoU-statistikk	X	
FoU finansiert av næringslivet som andel av samlet FoU	NIFU/FoU-statistikk	X	
Antall deltakelser som prosjektpartner i Skattefunn-prosjekter	Skattefunn	X	
Øvrig samarbeid			
Andel artikler med samforfatterskap med offentlig sektor (herunder helseforetak)	Christin/NIFU	X	X
Andel artikler med samforfatterskap med forskningsinstitutter	Christin/NIFU	X	
Andel BOA-inntekter som andel av samlede inntekter	KD/DBH	X	(X)
Antall ledelser av klynger og sentra (SFF, SFI, FME, GCE, Arena, NCE)	Det enkelte universitet/ NFR	X	
Antall deltakelser i klynger og sentra (SFF, SFI, FME, GCE, Arena, NCE)	Det enkelte universitet/ NFR	X	
Bachelor- og masteroppgaver i samar-beid med eksterne og/eller som en del av forskningsprosjekter	Det enkelte universitet		
Antall delte stillinger som andel av faglige stillinger	NTNU	X	
Antall samarbeidsavtaler med bedrifter og offentlige virksomheter	Det enkelte universitet		
Mobilitet og delte stillinger			
Universitets-ansatte og studenters deltakelse i offentlige utvalg	Organbasen	X	
Antall professor II finansiert av eksterne kilder	NIFU/ Forskerpersonalregisteret	X	
Antall tidligere PhD. studenter med arbeid i innovasjonsaktive virksomheter	NIFU/ Doktorgradsmonitoren	X	
Kandidater utdannet fra universitet med arbeid i innovasjonsaktive bedrifter/virksomheter	NIFU/SSB-Registerdata	X	
Antall Nærings-PhD med det enkelte universitet som gradsgivende institusjon	NFR	X	

B. Indikatorer for direkte bidrag (resultater/endringer)			
3. Kommersialisering og næringsutvikling	Kilde	**Nasjonalt sammenlignbar**	**Internasjonalt sammenlignbar**
Inngåtte lisensieringskontrakter fra studenter og ansatte ved universitetet	DBH/TTO/FORNY	X	X
Registrerte bedriftsetableringer fra studenter og ansatte ved universitetet	TTO/FORNY/ Brønnøysund	X	X
Registrerte patenter fra ansatte og studenter ved universitetet	DBH/TTO/FORNY	X	X
Registrerte varemerkebeskyttelser fra ansatte og studenter ved universitetet	SSB/Patentstyret	X	X
Registrerte design fra ansatte og studenter ved universitetet	SSB/Patentstyret	X	X
NFRs STUD-ENT-tildelinger til universitetet	NFR/FORNY	X	
Rapporterte resultater om næringsutvikling fra SFF, SFI og FME og klynger	Universitetet/sentrene (se tabell 4.3)	X	
Rapporterte resultater om næringsutvikling fra andre NFR-prosjekter	NFR		
Rapporterte resultater om næringsutvikling fra EU-prosjekter	EU		

4. Innovasjon i offentlig sektor og samfunnet for øvrig			
Antall innovasjoner fra helsesektoren i samarbeid med universitetet	Helseforetakenes system for innovasjonsutvikling	X	
Priser og utmerkelser (bl.a. for godt design)	DOGA m.fl.		
Kvalitative eksempler på innovasjon i samfunnet med utspring i universitetet	Universitetet, basert på ulike metoder		
Resultater av universitetets kunstneriske utviklingsarbeid	Research Catalogue for aristic research		