Collaboration and SDG-related research at the University of Stavanger

Brökel, Heike and Broekel, Tom

University of Stavanger Business School, Norway, University of Stavanger Business School, Norway

28 October 2023

Collaboration and SDG-related research at the University of Stavanger

Heike Brökel[1] and Tom Broekel[2]

28.10.2023

[1]Department of Innovation, Leadership, & Marketing, University of Stavanger, Norway, heike.brokel@uis.no

[2]Department of Innovation, Leadership, & Marketing, University of Stavanger, Norway, tom.brokel@uis.no

Contents

List of Figures

List of Tables

1 Executive summary

This report offers a comprehensive exploration of research collaboration at the University of Stavanger (UiS) and its alignment with the United Nations' Sustainable Development Goals (SDGs). Drawing from the Cristin database, the analysis provides a detailed perspective on the evolving academic activities and collaborative patterns at **UiS**.

Key findings include:

International Collaboration: A pronounced shift towards collaborations involving external researchers underscores **UiS**'s move towards an internationalized research environment. **Intra-UiS Collaboration**: While collaborations within individual departments thrive, signifying the strength of close-knit research communities, broader interdisciplinary collaborations spanning faculties remain relatively rare. **Network Dynamics**: The internal collaboration network at **UiS** has evolved from isolated clusters to a more integrated framework. Researchers serving as central nodes or 'hubs' play a pivotal role in connecting diverse clusters, signifying a move towards a more interconnected academic ecosystem. **SDG Alignment**: A strong correlation was observed between the nature of collaborations and SDG alignment. Interdisciplinary collaborations often produce outputs resonating with SDGs, emphasizing the multifaceted nature of these goals. Moreover, researchers with central positions in the collaboration network significantly influence SDG-aligned outputs. **Language Preference**: English has progressively emerged as the preferred medium for research outputs, marking a trend towards global academic resonance.

In essence, the report illuminates the multifaceted dynamics of research collaboration at **UiS**, emphasizing the potential for bolstering interdisciplinary endeavors and underscoring the critical roles individual researchers play in shaping **UiS**'s contributions to global sustainability goals.

2 Introduction

When teams inside an organization work together, they can share their different skills and knowledge. This teamwork helps them better understand and solve big problems, like those related to the environment and society. For example, when companies are trying to be more sustainable in everything they do, teams from research, marketing, and finance all need to be on the same page (van Zanten and van Tulder (2021)). Universities, too, are bringing together teachers and researchers from different fields to address big issues (Cottafava et al. (2022)).

One of the biggest urgent and formidable challenge are the United Nations' Sustainable Development Goals (UN SDGs) we're all aiming to fulfill by 2030. The world is facing many problems that are all linked together. To solve these problems, we need to look at them from many different angles. Researchers have been trying to figure out how people from different areas can work together to address these issues (DiVito et al. (2021)). While we know that different organizations working together is helpful (Kobarg et al. (2020)), we're still trying to understand how different teams inside a single organization can collaborate effectively.

With this in mind, the report digs deeper into how collaboration takes place within the University of Stavanger and to what degree researchers already contribute to the UN SDGs. Specifically, it was explored how collaboration patterns between individuals, departments, and faculties have developed over time. How closely **UiS** research relates to the seventeen SDGs set by the UN was examined as well. More precisely, it was observed whether **UiS**'s research has been increasingly focusing on these goals. Lastly, it was studied whether **UiS** internal collaborations contributed to research aligning with the SDGs.

Before presenting the empirical results, the underlying database is introduced to provide relevant background informa-

tion and point out potential issues that need to be considered when interpreting the results.

3 The empirical basis

3.1 The Cristin-Database

Cristin (Current Research Information System in Norway) is a database, where (academic) publications are registered.

The Current Research Information System is a platform dedicated to the collection and dissemination of information related to Norwegian research. Its primary function is to centralize research data from various initiatives across Norway, making it accessible to interested parties. In addition, the system aids in streamlining research administration by facilitating the reuse of research information. Another essential role it plays is in monitoring and reporting scientific publications to institutions such as the Norwegian Ministry of Education and Research and the Ministry of Health and Care Services. Information is integrated into the system through two primary methods: manual registration by individual researchers and automated collection by the organization (SIKT), which retrieves data from other platforms and makes it available through the system.

3.2 UiS at a glance

Via the R-package **rcristin** and the public API of **Cristin**, all available research output information of the University of Stavanger (institution number "217") was retrieved, containing names and affiliations of researchers and their output, including, but not limited to books, articles, lectures, presentations, interviews, opinion pieces, reports, and posters. In total, information of 74,725 unique items was extracted.

The earliest output for **UiS** dates back to 1963, and although the retrieval was done 04.05.2023, the latest data is from 2024, due to upcoming papers, that are already registered now, although not being published yet.

In the **Cristin** database every researcher should be identified with a unique **ID** consisting of 1 to 7 digits. However, there are some impediments inherent. Some IDs are associated with multiple names. These names can differ because of the consideration of middle names, abbreviations of first names, spelling errors, or special characters. In addition, there are many cases in which the same name is associated with multiple IDs, which is usually the case for common names. Lacking the resources to clean such inconsistencies, we relied on the **ID** number as unique identification of researchers. That is, if the same researcher is assigned to two **ID**s, he or she was treated as multiple "virtual" researchers. If an **ID** is associated with multiple names, the name mentioned on the largest number of research items was used. While there are multiple instances in which the association between **ID**, **name**, and true identity of a researcher was unclear, it is not a major problem and primarily concerns only a few special cases.

Based on this approach, in total 6,240 researchers affiliated with the University of Stavanger were identified. Over the entire period, they account for 74,725 unique items registered in **Cristin**. Accordingly, the average researcher at **UiS** has registered 11.98 items over the whole period. Table 1 summarizes this information.

Table 1: Overview of UiS in Cristin

Characteristic	Value
UiS persons	6,240
UiS items	74,725
Items per UiS person	11.98

There is quite some variation in the numbers across years. Table 2 shows the corresponding values for every single year since 2012. When abstracting from the incomplete data in 2023, a positive trend is clearly observable with an average annual growth rate of the number of researchers of 6.93%, the average annual growth rate of the number of items being 4.67%, and that of the number of items per researcher of -2.09%. Accordingly, **UiS** is not only growing in terms of researchers registering results in **Cristin**, all researchers also increase their individual annual research output.

Table 2: Development of UiS in Cristin

Year	UiS items	UiS persons	Items per UiS person
2013	3,468	770	4.50
2014	4,065	879	4.62
2015	4,189	952	4.40
2016	4,170	1,029	4.05
2017	4,612	1,159	3.98
2018	4,871	1,240	3.93
2019	4,912	1,250	3.93
2020	3,959	1,183	3.35
2021	4,535	1,300	3.49
2022	5,230	1,407	3.72

3.3 Categories of research output

The **Cristin** database includes a categorization of the research output into 68 distinct types. Some of these categories are not well defined or even unclear in their meaning. For instance, the classification makes a distinction between *academic lecture*, *lecture*, and *popular scientific lecture*. Another example of an unclear differentiation are the distinct categories *academic article*, *academic chapter/article/conference paper*, and *popular scientific article*. In light of such fuzzy categories, one has to interpret the distribution of the research output across these with some care. Nevertheless, when aggregating across all years, it became apparent that *academic lectures* is the dominant type of output with the categories *academic article* being the second most important, and *lecture* and *interview* being a close number three and four. Figure 1 illustrates the distribution of items across all categories with at least 800 registered entries.

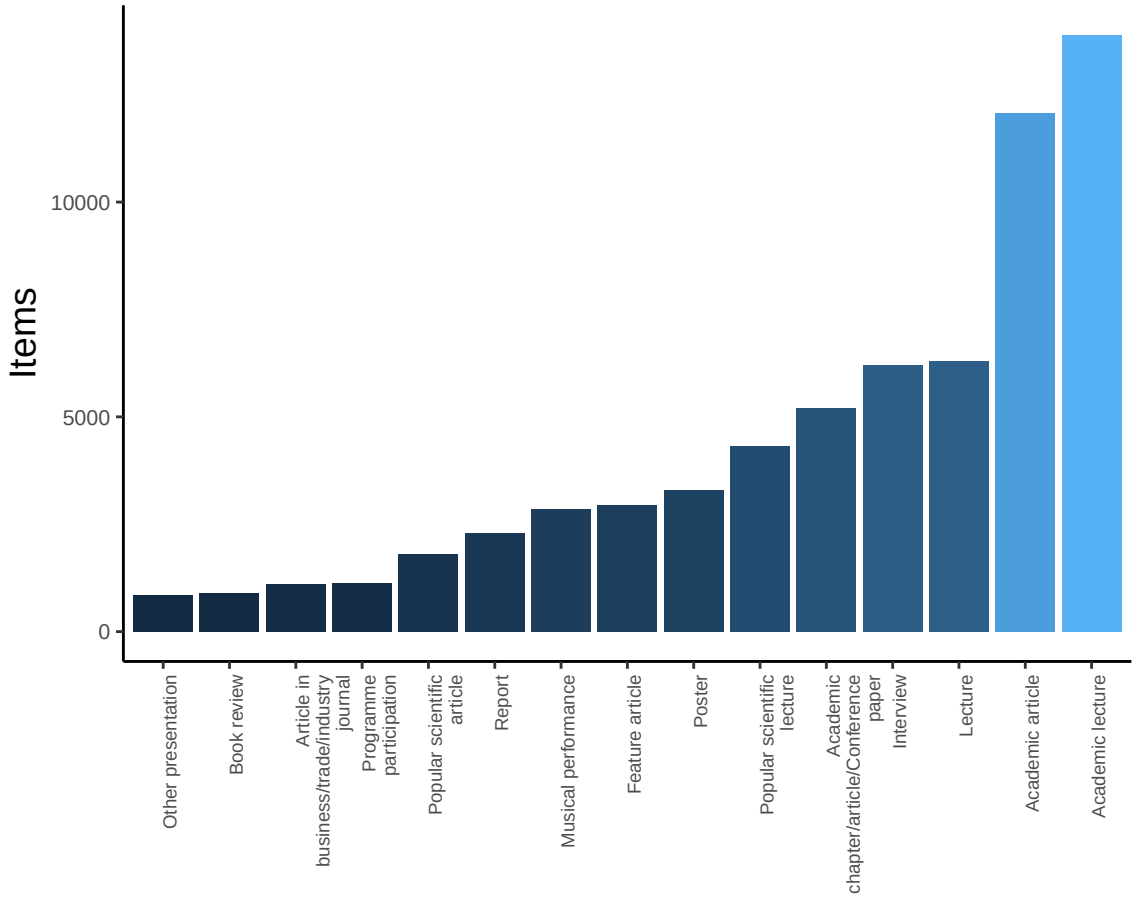

Figure 1: Categories of items

Thanks to the longitudinal nature of the data, it can be explored what types of research output have become more important over time. Figure 2 visualizes the changes in the distribution between 1996 and 2022. The category **Lecture** has seen the largest growth with an annual growth rate of about 34.54%. Of the major categories **Articles** and **Academic Lectures** show impressive average annual growth rates of 8.94% and 14.83%, respectively. Consequently, these drive the growth of the university's total output whereas categories such as **Posters**, **Reports**, and **Book reviews** remain more or less niche outputs.

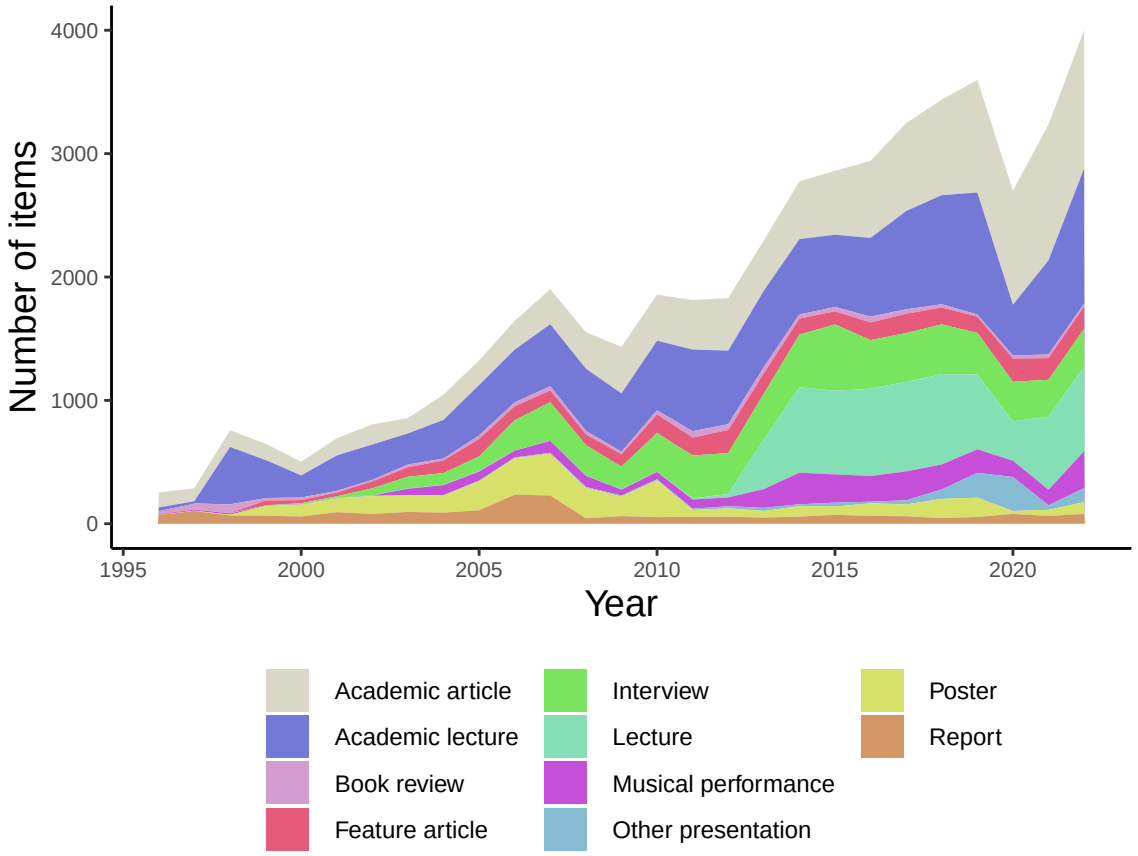

Figure 2: Categories over time

As discussed in the previous section, this increase in core academic output is driven by **UiS** increasing their staff but also by individuals producing more. With its growing output of academic articles (many of which are peer-reviewed), the university contributes to the global trend of exploding publication numbers (see, e.g., Wuchty et al., 2007).

Noticeably, **Musical performances** and **Interviews** register impressive growth rates (17.04 and 24.48%) indicating a growing engagement of university staff in outreach activities beyond their immediate peer groups. This aligns with the call for a *third mission* of higher education institutions (Etzkowitz & Leydesdorff, 2000).

3.4 Enriching the data with Scopus

While the **Cristin** database contains a lot of information, it is incomplete in a number of dimensions. One, that is relevant to describe the research output and content of **UiS**, are the summaries of said output as well as additional bibliographic information including citations and keywords. Lacking this information in **Cristin**, it was extracted from another publicly accessible database, namely **Scopus**. Together with Google Scholar and Web of Science, Scopus is one of the largest abstract and citation databases of peer-reviewed literature in the world, encompassing scientific journals, books, and conference proceedings (see for a review, Harzing & Alakangas, 2016). Developed and maintained by Elsevier, Scopus provides a comprehensive overview of the world's research output in the fields of science, technology, medicine, social sciences, arts, and humanities. The database offers various tools to track, analyze, and visualize research, facilitating a comprehensive insight into the academic research landscape. Researchers and institutions use Scopus for literature reviews, citation analysis, and to assess research trends and patterns across disciplines.

To link the **Cristin** and **Scopus** database, when available, the Digital Object Identifier (**DOI**) was extracted from **Cristin**. With this, the public **Scopus** API was used to obtain the relevant bibliometric information. Given that **Scopus** focuses on scientific books and peer-reviewed articles, this approach primarily enriched the information for items in the category **Academic article** that are written in English.

Of the 74,725 unique items registered in **Cristin** for **UiS**, 10,859 have been assigned to a DOI. Based on this, abstracts were added to 8,399 items in the database. For 5,543 items, keywords were matched whereby these items are not necessarily the same for which an abstract was obtained. Figure 3 highlights the increasing assignment of DOIs to items in the category **Academic article**. This enriched data will become essential when assessing the contribution of **UiS** to the SDGs.

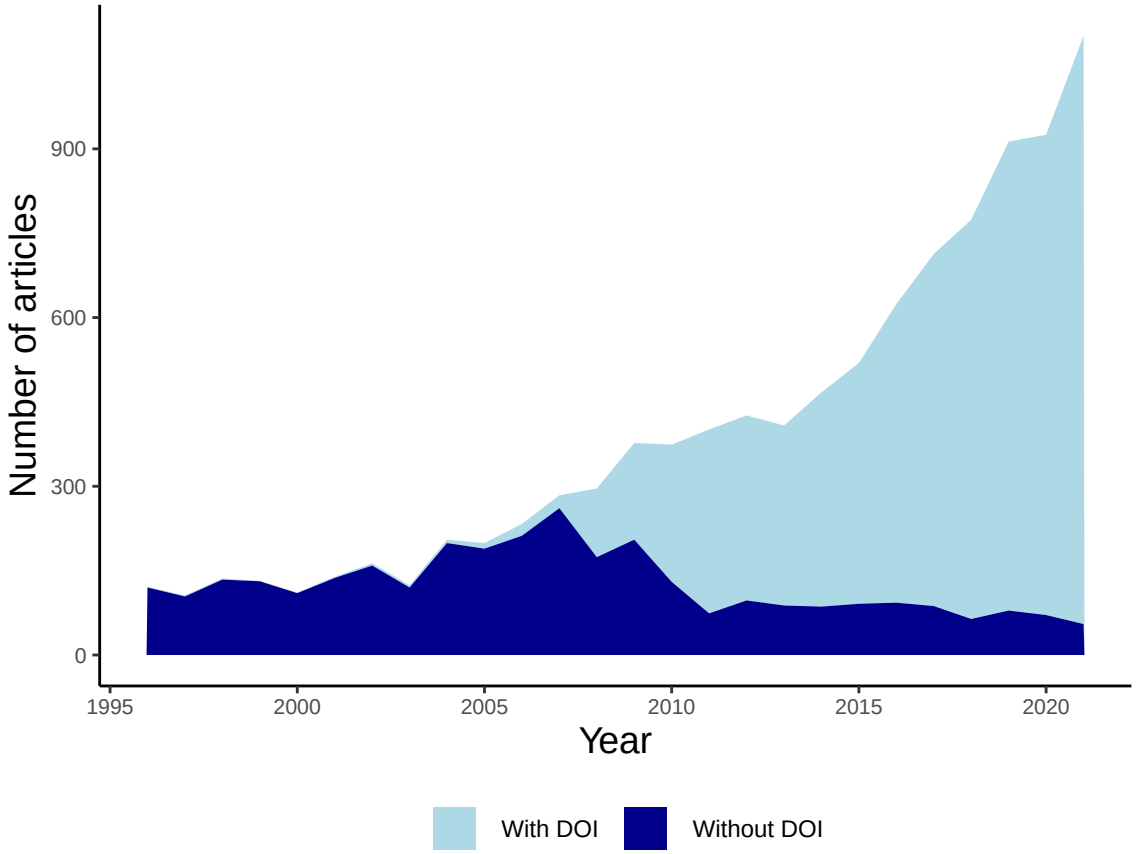

Figure 3: Articles and DOI

4 Language used in research output

The university operates in an international environment and as such scholars face a crucial decision of whether to publish their output in the domestic language, here Norwegian, or in English. When considering the landscape of academic publishing, the dominance of English as the primary language of scholarly communication is evident. This prevalence offers several advantages for researchers. Publishing in English allows research findings to reach a vast global audience, especially since many of the high-impact international journals are English-based. This, in turn, can lead to a higher potential for citations, given the broader readership. Additionally, communicating research in English can foster increased opportunities for international collaboration. Many academic institutions and funding bodies also prioritize or

give preference to publications in renowned international journals, further incentivizing English publications for career advancement and grant acquisition.

However, publishing in the domestic language, such as Norwegian, presents its own set of unique advantages, especially when the research topic has specific local or regional relevance. By publishing in the domestic language, researchers can ensure their findings are accessible and immediately applicable to local policymakers, practitioners, and the general public, who may not be as proficient with English specialist literature. This is particularly crucial for studies that delve into region-specific issues, cultural nuances, or local phenomena, where the primary audience is the local community. Moreover, publishing in the native language can help preserve and promote linguistic diversity in academia, ensuring that scholarly discourse isn't limited solely to those who speak and understand English (Pudelko & Tenzer, 2019; Thingnes, 2020).

Nonetheless, there's a counterpoint: while publishing in the domestic language supports local relevance and inclusiveness, it might limit the global reach and impact of the research. Given the digital age and the interconnectedness of the global academic community, a balance must be struck. Some researchers opt for a dual approach, publishing detailed findings in their native language for local audiences and broader overviews or associated pieces in English for the international community. So how are **UiS** scholars positioned in this context?

The **Cristin** database includes information on the language of the research output. In total, the share of entries written in Norwegian (labeled as *no*, *nb*, or *nn*) is ca. 52% (39,148 of 74,725 total unique items). The share of research output in English (labeled as *en*) is around 42% (31,430 items). Other languages account for six percent of the research output. Looking at the total output ignores crucial differences between different types of research outputs as well as important developments over time. Figure 4, therefore, presents the share of items in Norwegian and in English for the two most important output categories **Academic articles** and **Academic lectures**.

There is a clear trend of increasing publications in English (category **Academic articles**), suggesting that **UiS** scholars value contributing to the international scientific community more than potentially stronger local outreach. Consequently, Norwegian decreased in this category. However, noticeably, the trend seems to lose speed and there are even some indications for a reversal. There seems to be a relatively stable basis of roughly about five percent of academic articles being published in Norwegian.

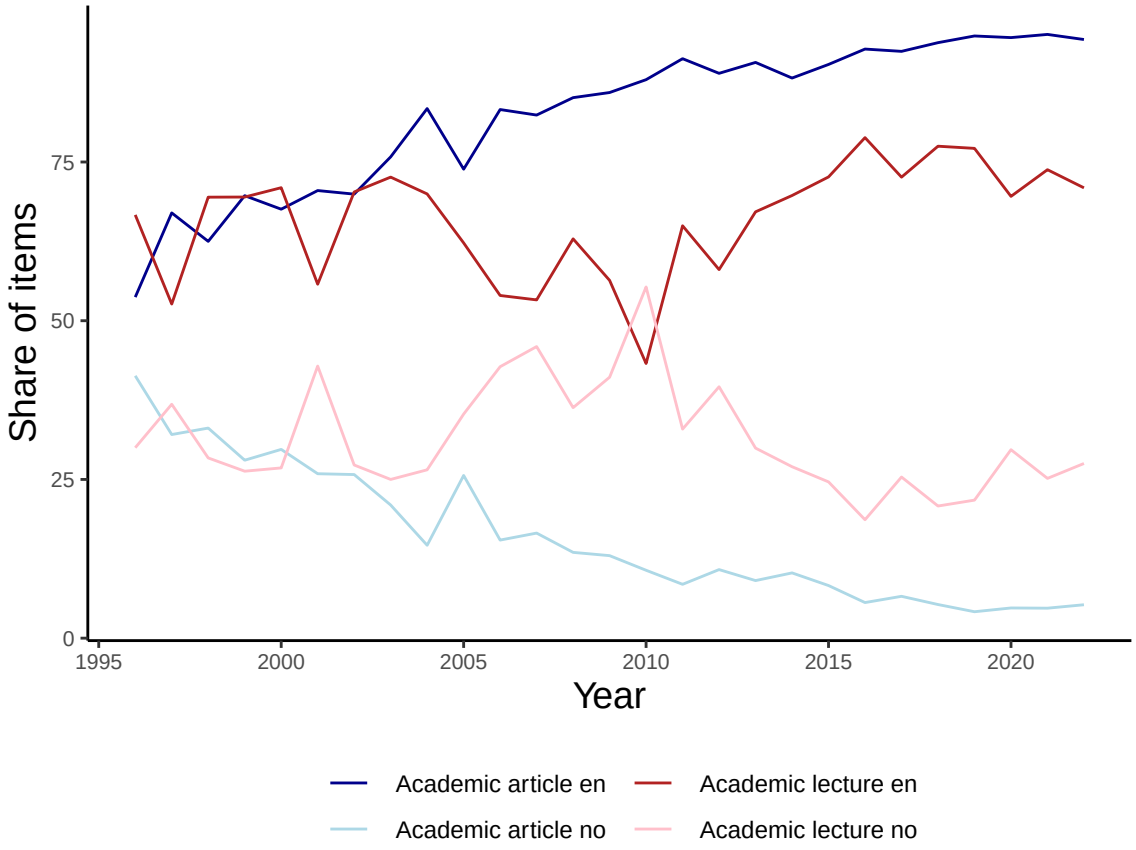

Figure 4: Use of language

The story is different for **Academic lectures**. Here, the share of lectures held in Norwegian fluctuates around 31.47% and that for English around 69.65. Noticeably, the share of Norwegian lectures was significantly larger between 2004 and 2012 than in the periods before and after, with a maximum value of 55.32 in 2010.

5 Collaboration activities of UiS scholars

5.1 General collaboration patterns

The academic landscape is undergoing a transformation, emphasizing not just individual brilliance but also the synergy of collaborative effort. The study by Wuchty et al. (2007), "The Increasing Dominance of Teams in Production of Knowledge," offers insights into this shift. Analyzing a vast array of publications, they observed a growing trend favoring team-produced research over solo endeavors. Such collaborative works not only dominate academic outputs but also garner higher citation rates, indicating their broader impact and acceptance in the scholarly community.

While there is a lot of emphasis on international collaboration, an important type of collaboration frequently gets overlooked: intra-organizational collaboration. Meaning, individuals belonging to the same organizations pool their competencies and, with or without additional partners, engage in creative and productive activities. In the context of higher education, departments and faculties traditionally operated in silos, each nurturing its specialized knowledge. However, the complexity of modern research questions, especially those related to the sustainability goals, necessitates an interdisciplinary and, in consequence, cross-faculty and cross-department, approach. By fostering intra-university col-

laboration, institutions can harness a rich tapestry of expertise, methodologies, and perspectives, all under one roof. This not only enriches the research output but also ensures a holistic approach to problem-solving. Last, but certainly not least, it may greatly contribute to scholars' feelings of belonging and the development of a shared identity. Yet, it is essential to approach this trend with a balanced perspective. While collaboration can lead to diverse insights, it also brings challenges in communication, alignment of objectives, and resource allocation. Institutions must, therefore, strike a balance, promoting collaboration while also addressing its inherent challenges, ensuring that the collective pursuit of knowledge remains both productive and harmonious.

In any case, while many universities are very transparent about their national and international collaboration, fewer monitor and analyze the intensity of intra-organizational joint works. Thanks to the **Cristin** database, we are in the fortunate situation to shed light into **UiS** researchers' general collaboration activities and their engagement within **UiS**.

To discern joint and collaborative endeavors, the overlap of **Cristin** person IDs with **Cristin** item IDs was analyzed. Specifically, when two unique person IDs link to a single item ID, this was viewed as evidence of a collaboration. It is crucial to highlight that this tends to measure collaboration activities at the time when they have produced some output. Usually, it implies that the actual collaboration took place before the time it is observed in the form of co-created **Cristin** items. This should be taken into consideration when interpreting our collaboration indicator. Given the notable variances across disciplines regarding this time gap, the data was interpreted in its raw form, using the item's **Cristin** registration date as a proxy for the collaboration year.

Furthermore, each **Cristin** individual has an associated specific organizational (sub)unit. To elaborate, the linked organization ID possesses a hierarchical configuration, with dots demarcating distinct organizational tiers. The initial segment (prior to the first dot) signifies the legal entity; for **UiS**, this is *217*. The ensuing segment pertains to the faculty, such as *14* for the UiS Business School. Subsequent portions, like *01*, denote the department (if present). By dissecting this ID, entity-specific insights can be generated. For example, all publications recorded by members of a particular department can be tallied. Likewise, the **Cristin** items can be quantified to which individuals from two separate departments have contributed, providing insight into the collaboration magnitude between these departments.

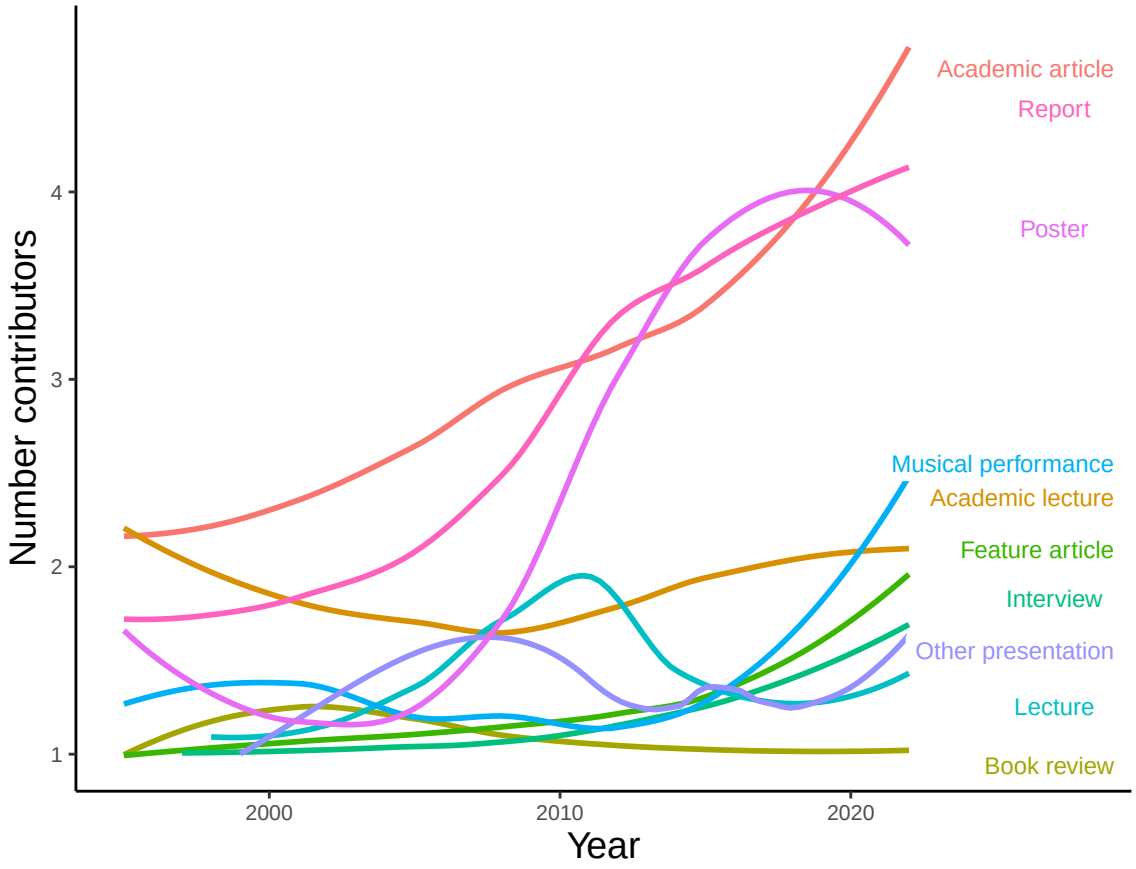

Figure 5: Collaboration over time

Looking at the development at **UiS** between 1995 and 2022, the general trend in academia of activities becoming more collaborative is apparent for this institution as well. Figure 5 shows the smoothed trends of the average numbers of contributors per item registered in **Cristin**. Most trends are characterized by a significant positive slope. For instance, the number of co-authors of academic articles increased from 2.48 in 1995 to 4.8 in 2022. The average annual growth rate of co-authors per year is 3.28%. In contrast, academic lectures only saw an increase in the number of contributors by 0.38% on average per year. The growth in the number of co-authors of book reviews was similarly low with on average 1.4% per year. Consequently, while collaboration becomes more common, there is some heterogeneity with respect to the type of academic output.

However, that is not the only type of heterogeneity. There are also noticeable differences in terms of collaboration intensity between the faculties of **UiS**.

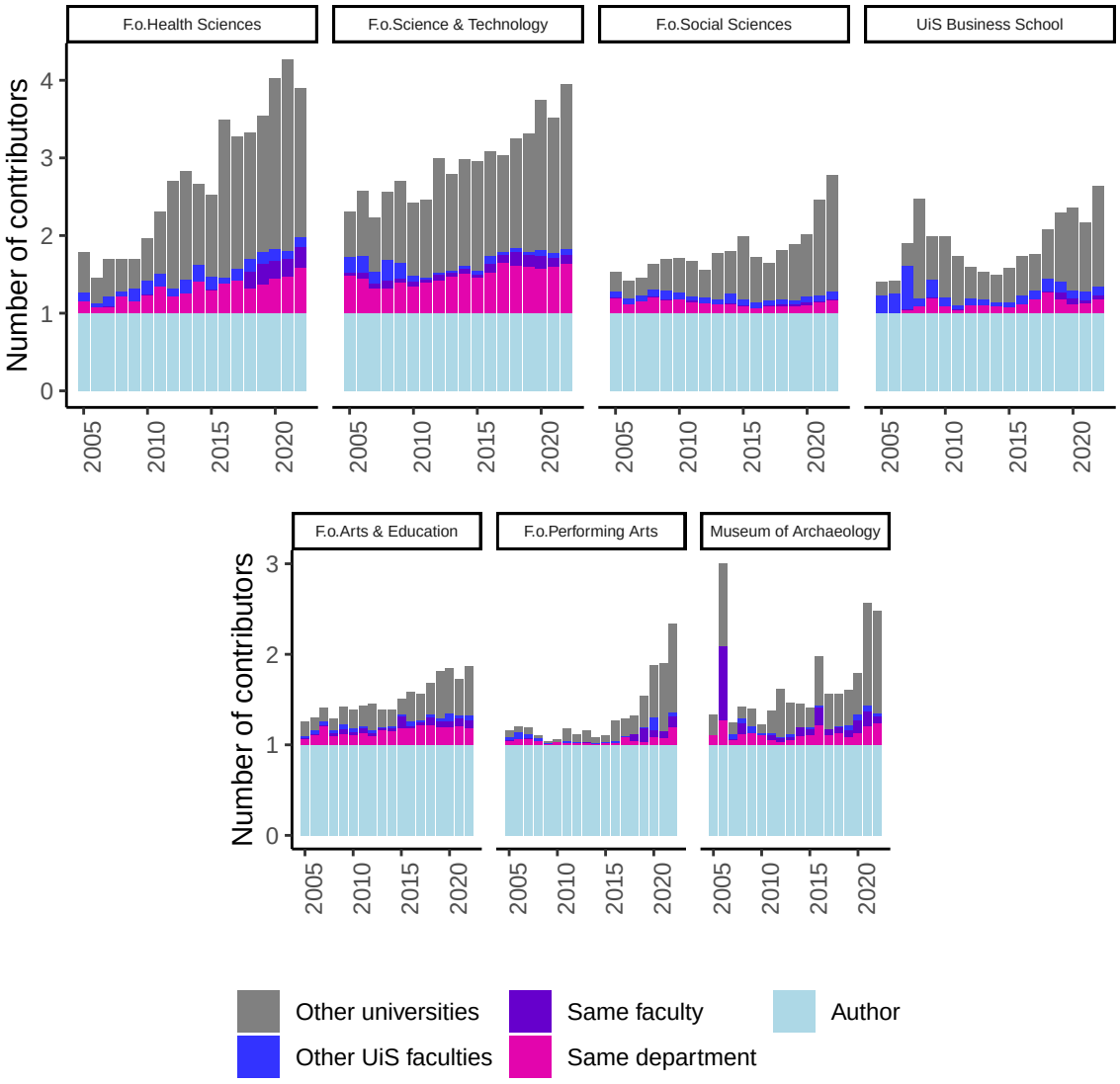

Figure 6: Collaboration activities by faculty

Figure 6 gives a general overview of the extent **UiS** researchers of different faculties engage in collaborative work. The figures are based on information for academic output in all output categories, i.e., it simultaneously considers joint **Academic lectures** and joint **Academic articles** as well as all other output types. In the present context, this is a great advantage of the **Cristin** database, which is not limited to a specific output. By aggregating all output types, the numbers become more comprehensive and inclusive than what is presented in common bibliometric studies that usually focus on **Academic articles**. In particular, this concerns the heterogeneity of faculties in terms of their preferred output types.

Clearly, scholars at each of the main faculties have increased their collaborative activities since 1995. The growth is particularly strong for the *Museum of Archaeology* with an average year-to-year growth rate of 7.31%. The *Faculty of Health Sciences* also experienced a strong growth in collaboration with an average year-to-year growth rate of 4.3%. The somewhat smaller growth rates of the *Faculty of Science and Technology*, with 2.29%, is partly due to its already relatively high level of collaboration in 1995. Interestingly, the *UiS Business School* and the *Faculty of Arts and*

Education tend to show lower growth in collaborative research.

Figure 6 provides even more insights. The magenta-colored area visualizes the number of contributors per item who are from the same department as the focal contributor. In 2022, it was the *Faculty of Technology and Science* that registered the highest count of 0.64 of contributors from the same department, followed by the *Faculty of Health Sciences* with 0.59. In contrast, intra-department collaboration is relatively rare at the *Faculty of Social Sciences* and *UIS Business School* with 0.17 and 0.18, respectively. Whether this is due to the different size of departments or the nature of the underlying type of research is beyond the scope of the present report. Interestingly, the number of contributors that work at the same department appears to be relatively stable. However, it has somewhat decreased at the *Faculty of Social Sciences* from 0.2 in 2005 to 0.17 in 2022. In contrast, the *Faculty of Health Sciences* saw the number grow from 0.15 in 2005 to about 0.59 in 2022.

While intra-department collaboration is not common, collaborations between departments at the same faculty are even less frequent (the purple area in Figure 6). In 2022, the *Faculty of Health Sciences* reports the average **Cristin** item, with 0.26 contributors from the same faculty but different departments. This is already the highest value among all faculties. For the *Faculty of Social Sciences* the number is as low as 0.02. While the number is more than twice as much for the *UiS Business School* at 0.05, it is still just a fraction of that of the *Faculty of Health Sciences*. Some of this variance may be explained by the number of departments that differ between faculties. For instance, the *Faculty of Science and Technology* has a registered number of 8 departments and the *UiS Business School* only 3. However, cumulatively over all years, the *Faculty of Health Sciences* has registered 4 distinct departments, which is the same as the *Faculty of Social Sciences* with 4. Accordingly, other factors seem to be more relevant, and should be investigated in more detail in the future. Nevertheless, with the exceptions of the *Faculty of Social Science* and the *Faculty of Performing Arts*, from 2015 onward, most faculties seem to have established a small but stable quantity of such collaborations.

A similar picture is obtained looking at cross-faculty collaboration (the blue area in Figure 6). With the exception of the *Museum of Archaeology* and the *Faculty of Performing Arts*, each **Cristin** item has about 0.11 contributors from other faculties than that of the focal contributor. For the *Museum of Archaeology* this number is only 0.05 and for the *Faculty of Performing Arts* it is 0.02. Consequently, these two faculties appear to be relatively less connected to the rest of the university. In contrast, the *Faculty of Health Sciences* ranks highest with an average number of 0.14 contributors from other faculties per item.

This metric solely accounts for whether a collaboration involves a distinct faculty, without delving into the diversity of such partnerships. For instance, while researchers from the *Faculty of Health Sciences* may frequently collaborate with another faculty, they might consistently work with the same one. On the other hand, the *Faculty of Performing Arts* might exhibit fewer collaborative projects, but those collaborations could span a broader range of faculties compared to the *Faculty of Health Sciences*.

This will be investigated in more detail when applying a network perspective, see **Section 6**. Figure 6 shows that this number fluctuated relatively stronger over recent years without a clear trend at any faculty.

Looking at all three numbers representing **UiS**'s internal collaboration, namely the number of co-contributors from the same department (magenta area), from the same faculty but other departments (purple area), and from other faculties (blue area), it becomes clear that such types of collaboration generally only play a small role at any faculty. When researchers engage in collaborative work, it is most likely with colleagues from other universities.

The grey area in Figure 6 captures the average number of contributors per **Cristin** item from outside **UiS**. Among the large faculties, it is the *Faculty of Science and Technology* that reports the highest number with on average 2.12

contributors per item. The *Faculty of Health Science* is a close second with 1.92. At the lower end of the list are the *Faculty of Arts and Education* and the *Faculty of Performing Arts* with values of 0.54 and 0.98 respectively.

In contrast to the other figures discussed before, the number of contributors from outside **UiS** has seen the greatest dynamics, or more precisely, the largest growth. For instance, the *Faculty of Science and Technology* has seen an average year-to-year growth of 7.91%. However, the greatest growth in this category is observed for the *Faculty of Performing Arts* with 17.16 and the *UiS Business School* with 12.41%. Both started from relatively low values, which explains some of the growth differentials. Nevertheless, when **UiS** scholars collaborate they primarily do so with researchers outside **UiS** and this trend is on the rise. Whether this is an expression of an increasing internationalization of research, or a growing embeddedness of the university in the (inter-)national science system will be examined in the following section.

5.2 Internationalization

Previously, it was shown that **UiS** researchers are increasingly collaborating and much of this involves contributors from outside **UiS**. The **Cristin** database allows for a more detailed look into external collaborations and into the development of international collaboration in particular. For the vast majority of contributors, the country of their affiliation is registered. Consequently, each affiliation outside **UiS** is treated as an indication of an external link/collaboration.

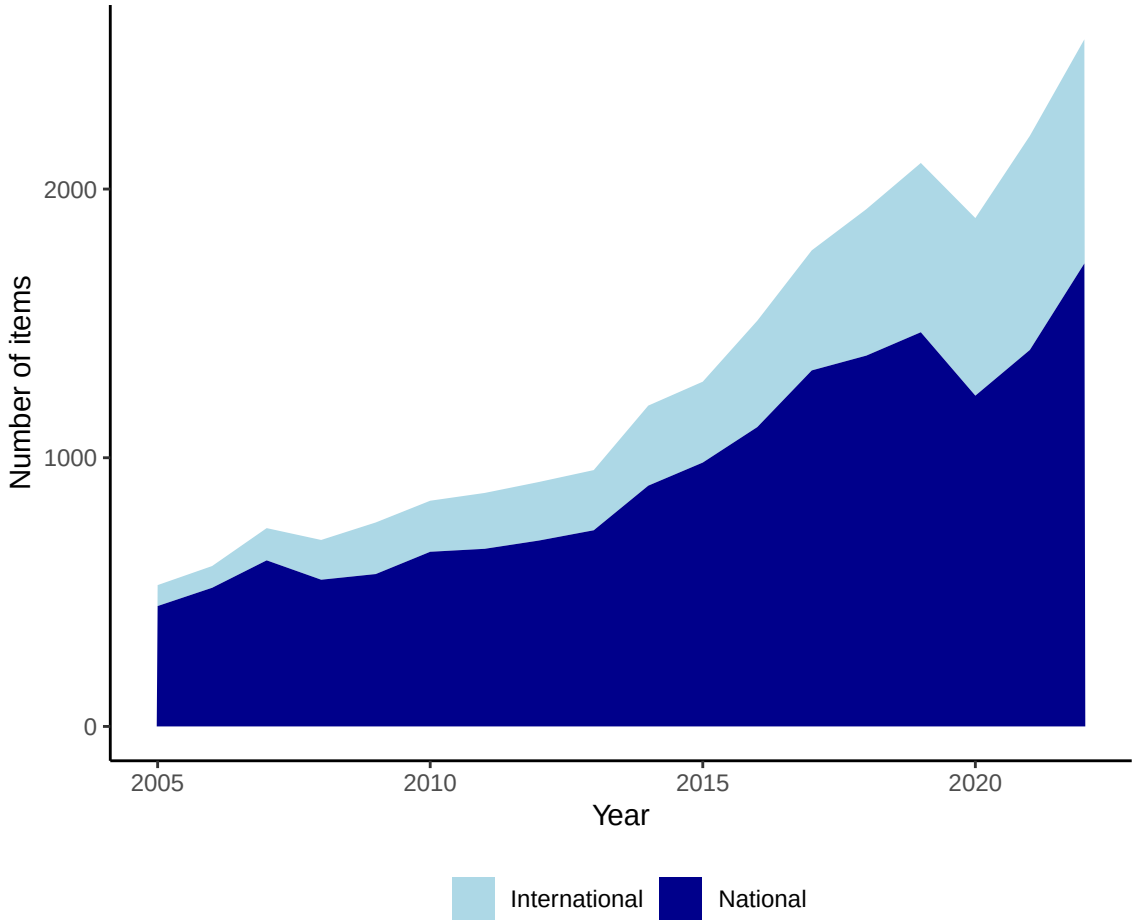

Figure 7: Internationalization of UiS research

The first insight into the extent of **UiS** scholars interacting with others are represented in Figures 7 and 8. Here, the underlying data is restricted to all **Cristin** items with at least two contributors to ensure that the information relates to actual collaboration activities and that the numbers are not distorted by the degree to which **UiS** researchers engage in non-collaborative activities. The stacked area plots compare the number of items with at least one contributor from outside **UiS** (light blue area) to the number of items with collaborators exclusively from within Norway including within **UiS** (the dark blue area). In other words, the light blue area represents the extent of international and the dark blue area the magnitude of national collaboration.

Figure 7 illustrates these numbers for the University of Stavanger as a whole and documents a noticeable and consistent rise in the absolute amount of international collaborations (displayed as the light blue area). Collaborative efforts have increased from 78 items with international participation in 2005 to 834 items in 2022. The average year-to-year growth rate was 14.96%. The number of research items with only domestic participants grew with a rate of 8.25%. The share of items with international partners rose from about 15% in 2005 to about 33% in 2022.

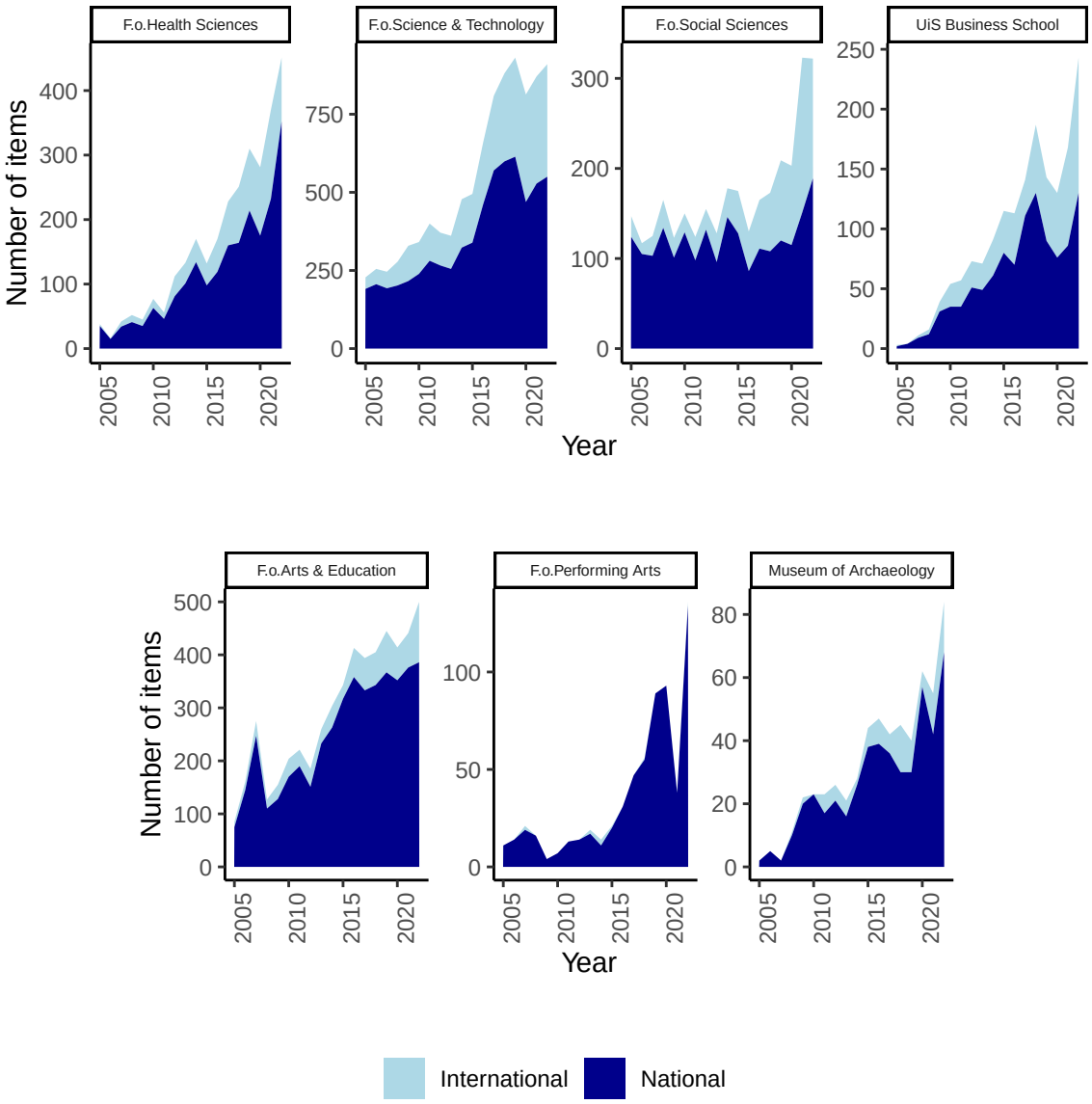

Figure 8: Internationalization of UiS research by faculty

Again, strong differences between **UiS**'s faculties are apparent. For instance, the *Faculty of Performing Arts* appears to be somewhat of an outlier, as it has managed to established very few international collaboration that translated into registered output. In contrast, the shares of international collaboration are quite substantial for the *Faculty of Science and Technology* (40%), the *Faculty of Social Science* (41%), and the *UiS Business School* (47%). Research at these faculties is intensively embedded into the international research landscape and it has shown an impressive growth in recent years. For instance, the *UiS Business School* showed the highest average year-to-year growth in the number of items with international participation of 32.06%, doubling that of the *Faculty of Science and Technology* of 14.32. But an impressive growth is also observed for the *Faculty of Health Sciences* with 22.84%.

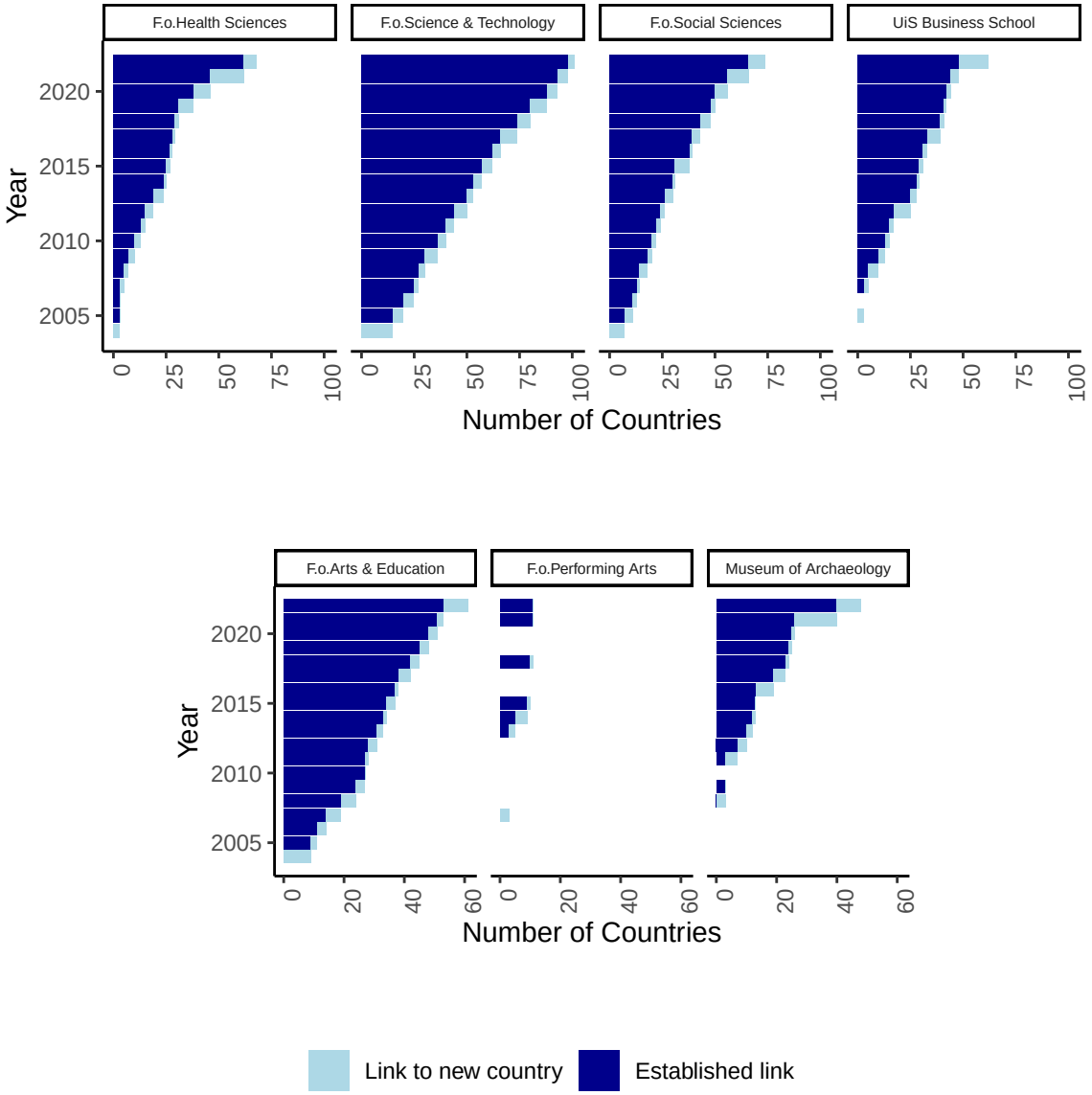

Figure 9: Countries added by faculty

In Figure 9, the dark blue area represents the cumulative number of countries to which at least one link was established in the past and the light blue area the number of countries that are added to this pool in the respective year. Hence, the figure provides some insights into how the individual faculties have internationalized over time. More precisely, it

shows the extent and timing of new countries being added to faculties' existing portfolio of countries. In this context, link means that at least one scholar had been in a collaboration with a researcher from this country before. Again, some differences between faculties are striking. The *Faculty of Science and Technology* establishes links to new countries on a relatively constant basis. So far, it has registered connections to 101 countries. The *Faculty of Social Sciences* and *Faculty of Health Sciences* are not far behind with 74 and 68 countries respectively. However, they increased their connections to foreign countries in a less continuous manner and experienced a large push in this dimension in recent years. Similar is true for the *UiS Business School*, which added 14 countries in 2022. In future analyses it will be interesting to explore to what degree such developments are driven by the hiring of new international staff or by researchers actively reaching out to new communities and countries via (subsidized) research projects.

The possibilities for involving international partners is to a certain degree conditional on the type of project. While it is rather straightforward to collaborate with someone from another country in the context of a scientific publication, it is more difficult to make this happen when it comes to e.g., a (local) academic lecture. Therefore, it is interesting to take a look at individual categories of research output and assess the process of internationalization. Figure 10 does this for the most prominent output category the *Academic article*. Comparing this figure to Figure 9 (all output), it becomes clear that the degree of internationalization is higher for most faculties when just looking at this type of research output. For instance, the *UiS Business School* reports about 82% of this output to involve international collaboration. For the *Faculty of Science and Technology* and the *Faculty of Social Science* the percentages are a bit lower at 60 and 63%. Nevertheless, they still exceed fifty percent. This is a clear sign of the importance of international collaboration for research. For **UiS** as a whole, about 60% of its *Academic articles* in 2022 featured international collaboration.

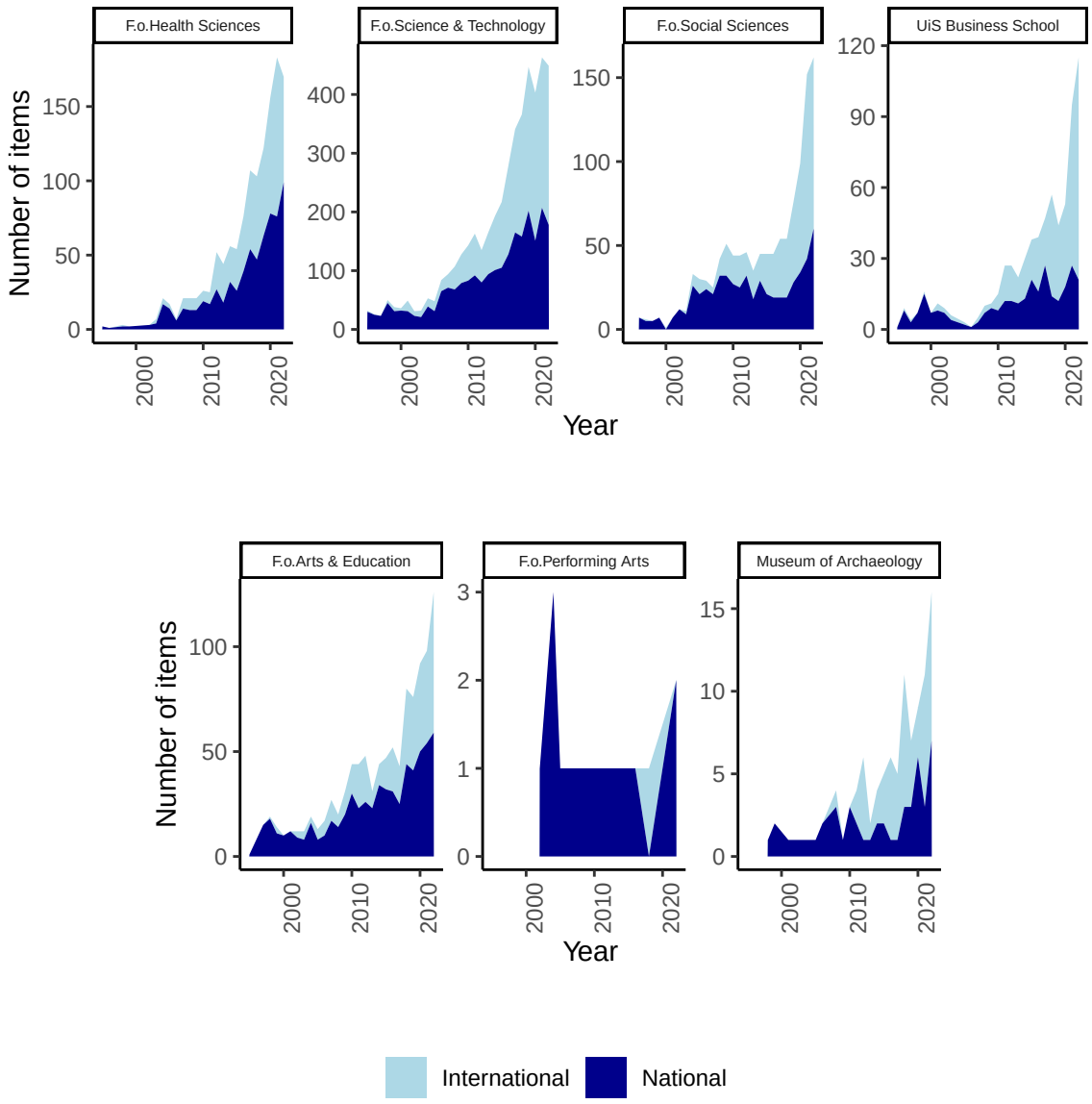

Figure 10: Internationalization of Academic articles

6 From collaboration to a network perspective

6.1 Why networks?

In the previous analysis, the focus has largely been on bilateral collaborations—two entities (scholars) coming together to combine expertise and resources. However, it has become increasingly apparent that this perspective is rather limited and additional insights can be gained by zooming out and looking at the broader landscape of the web of interconnected relationships forming intricate knowledge networks (Uzzi, 1996).

This shift to a systemic perspective of networks is essential for several reasons. Seminal research emphasizes the value of such a network perspective, suggesting that it is the embeddedness into networks that allows researchers and organizations to tap into a wider pool of ideas, which lead eventually to more groundbreaking discoveries. Crucially, it

is not just the intensity of embeddedness that matters in this context, but also the general structure of the network as such. The network perspective focuses on the structural features of such web of relationships considering not just direct links but also indirect ones. These "weak ties" or "distant connections", as pointed out by Uzzi (1997), can be instrumental in bridging diverse knowledge areas and introducing fresh perspectives (see on this also Burt, 1992). Moreover, within any network, certain nodes or entities, due to their position, hold more influence (Freeman, 1978). They often act as gatekeepers or brokers, connecting different parts of the network, facilitating knowledge flow and innovation (Broekel & Mueller, 2018). It is therefore important to identify which individuals or organizational entities hold such structurally important positions, as they determine the network's capacity to diffuse knowledge and withstand potential shocks. This applies to inter-organizational networks as well as intra-organizational ones. Specifically, within large organizations, understanding the internal network can reveal potential synergies, underutilized expertise, bottlenecks, gatekeepers, or even areas of internal competition.

In essence, the fabric of innovation is woven with threads of collaboration, both between and within organizations. By shifting the gaze from individual partnerships to the vast tapestry of knowledge networks, more of the richness and systematic nature of the collaborative endeavor can be grasped. It's a perspective that not only resonates with academics but holds profound implications for practitioners and the broader public. Consequently, it will be explored next.

6.2 UiS's internal collaboration network at the level of individuals

The collaboration network within the University of Stavanger can be visualized across various levels including individuals, departments, or faculties. Subsequently, each of these levels will be explored. At the most fundamental level, the collaboration network between individuals is described.

In this representation:

Nodes: Each scholar at **UiS** is depicted as a *node*.

Links: When research output, be it a poster, journal article, book review, or any project, is jointly produced by two scholars, a *link* or *connection* is established between their respective nodes.

Given that research collaborations often extend beyond a single year, years are typically grouped into periods for such network analyses. Following conventions (see, e.g., Boschma & ter Wal, 2007), every five years was aggregated into one period. This means that any collaborative research output recorded in the **Cristin** database within a five-year span was taken into account when links between researchers were identified.

For clarity purposes, the frequency of collaboration amongst scholars during a specific time frame is not distinguished. Instead, a singular link in the analysis represents the occurrence of minimum one collaborative effort. The periods are defined the following: **Before 2000** (which covers everything between the years 1963 and 2000), **2000-2004**; **2005-2009**, **2010-2014**, **2015-2019**, and **2020-2024**. The size (number of nodes) of the network makes it difficult to create an insightful visualization. Nevertheless, using the so-called *edge bundling* approach, a visualization of the main backbone network can be created and is shown for the period **2020-2024** in Figure 11[3].

[3]Edge bundling works by grouping together edges that follow similar paths or run closely parallel. Rather than displaying each individual connection, which can lead to a cluttered view, edge bundling combines these paths into bundled trajectories, resulting in a streamlined and visually appealing display. In this bundled network, nodes, representing individual scholars in the present context, are typically positioned around the circumference of the circle. The bundled edges, symbolizing collaborations, flow from these nodes, moving elegantly through the center of the circle. The density and thickness of these bundles can offer insights into the frequency and intensity of collaborations between nodes, with a thicker bundle indicating a higher number of collaborations. The impression of fewer nodes than the actual raw network is due to nodes with similar connection patterns are visually clustered, making them appear as a singular unit.

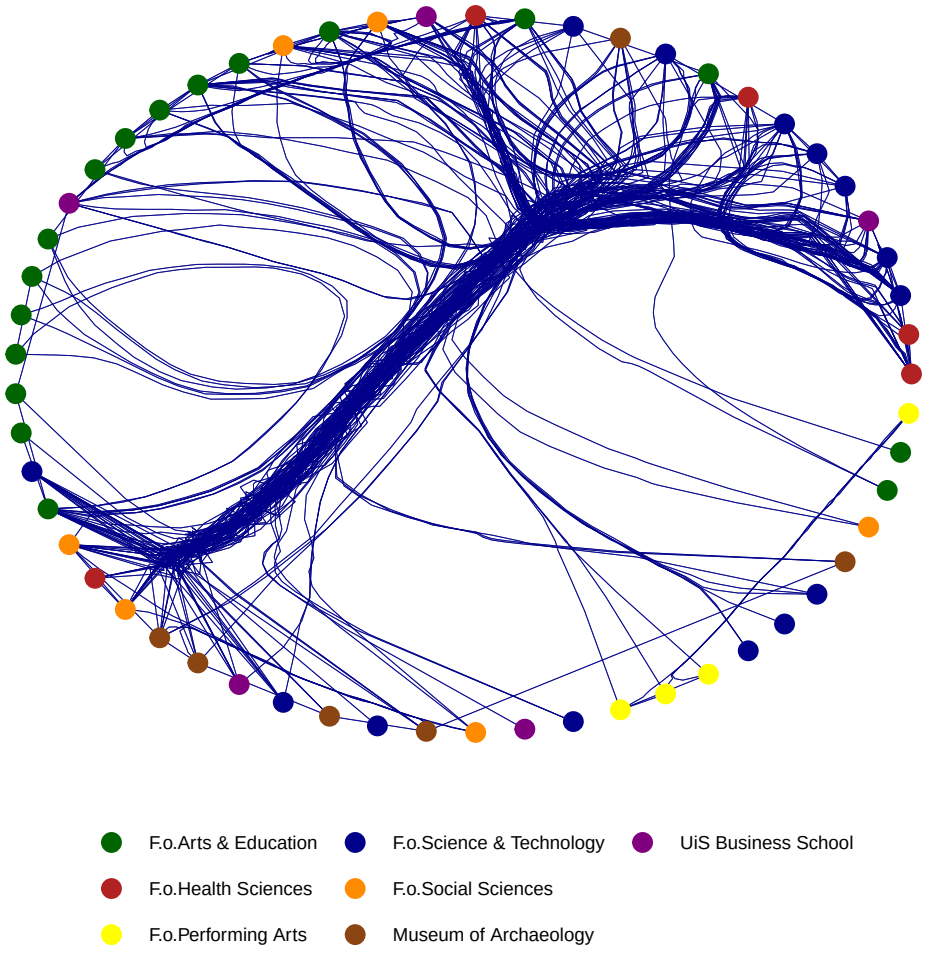

Figure 11: Backbone of UiS's internal knowledge network

While network visualizations are beautiful, when exceeding a certain size, they provide very little information. Therefore, the network will be described by a range of measures and indices developed in the field of *Social Network Analysis* (see, e.g., Freeman, 1978). Table 3 provides a snapshot of the evolution of scholarly collaboration at the University of Stavanger from a network perspective using a range of measures over different periods.

Table 3: UiS's collaboration network (individuals) - Basic stats

Period	Size	Density	Av.degree	Avg.path.length	Centralization.betweenness
Before 2000	1235	0.58	7.21	5.10	0.16
2000-2004	737	0.92	6.80	6.01	0.14
2005-2009	1208	0.66	7.94	4.59	0.15
2010-2014	1201	0.61	7.36	4.47	0.25
2015-2019	1812	0.52	9.47	3.37	0.12
2020-2024	1788	0.54	9.71	3.65	0.10

Size: Represents the total number of researchers (or nodes) active in the network during the specified period. The

observed growing network size suggests that the university has been expanding its faculties, or that a broader spectrum of scholars has been engaging in collaborative research. Although there are some significant fluctuations in the early periods.

Density: This metric provides a ratio of the actual connections (collaborations) to the potential connections. A density close to one indicates a highly interconnected network, where most scholars have collaborated with one another. A lower value, closer to zero, suggests that collaborations are more selective or specialized. For instance, the density of 0.92 during 2000-2004 suggests a phase where researchers were extensively collaborating, forming a cohesive academic community. Such cohesion can foster interdisciplinary research, but there's a caveat: too much interconnectedness might also lead to an echo chamber, limiting exposure to diverse ideas. The decreasing value in later years is most likely a statistical artifact, as density is known to decrease quasi-automatically when networks grow in size.

Av.degree: The average degree gives the average number of collaborations per researcher. A higher value indicates that, on average, a scholar at the University of Stavanger collaborates with more peers. This is a direct measure of how collaborative individuals are within the given time frame. Fluctuations in this metric could hint at shifts in research focus, funding availability, or institutional policies that either encourage or limit collaborative endeavors. In the present case it may also be related to more researchers registering their output in **Cristin**. In any case, it clearly indicates that research at **UiS** has become more collaborative over time, with the average researcher having 9.71 other **UiS** internal collaborators in the period 2020-2024.

Avg.path.length: This metric shows an average of the shortest paths between all pairs of scholars. In simpler terms, it's a measure of "degrees of separation." A lower value indicates that researchers are closely connected, even if they haven't directly collaborated. The measure remains relatively low across periods and decreases considerably, underscoring the increasingly tight-knit nature of the university's academic community. Even researchers who haven't directly collaborated are closely connected through mutual collaborators, facilitating the rapid exchange of ideas and knowledge. In 2020-2024, any random pair of researchers at **UiS** was just 3.65 steps away from each other. This is considerably lower than what is found in general for the global scientific community (Barabasi et al., 2002) and due to the smaller proximities (geographical, social, cognitive, institutional, and organizational) between **UiS** researchers.

Centralization.betweenness: This is a measure of how certain scholars act as 'bridges' or 'brokers' in the network. A higher value suggests that a few scholars are central to the network, possibly collaborating with diverse groups and thereby holding the network together. On the other hand, a lower value indicates a more decentralized network, where collaborations are more evenly distributed. For **UiS**, the measure is decreasing over time hinting at a more democratized collaboration structure, where knowledge exchange isn't overly dependent on a few central figures. This development makes the network more resilient, as the departure or reduced activity of a few key figures won't significantly disrupt the collaborative ecosystem.

More insights into the structural properties of the network are given in the advanced statistics in Table 4. Again it shows a number of metrics and their values during different time periods.

Cluster Coefficient: This metric assesses the extent to which nodes in a network cluster together. A higher clustering coefficient indicates that researchers tend to collaborate in tight-knit groups. Over the periods, the coefficient seems to peak around 2000-2004 and then gradually decreases, suggesting a potential shift from localized collaborations to more distributed ones.

Assortativity: This metric indicates the level of connectivity between nodes with similar degrees of connections to each other. A negative value, as observed across all periods, indicates that scholars with many collaborations tend to work with those with fewer collaborations and vice versa. In many cases, this results from established hence more

connected researchers working together with junior scholars who have fewer connections. This pattern has remained relatively consistent, though there's a slight increase in negative assortativity 2010 through 2019.

Number of Components: This is the number of distinct, non-overlapping subgroups in the network. A higher number suggests more isolated groups of researchers. The decline in this number, especially noticeable after 2014, indicates a trend toward a more interconnected scholarly community, something that previously discussed metrics (**density**, **ave.path.length**) have also indicated.

Share of Largest Component: This measure signifies the percentage of nodes in the largest connected component. A rising trend here, peaking in *2015-2019*, supports the growing cohesion in the network, with a dominant group of interconnected scholars emerging. This is further supported by the measure of **Modularity**, which evaluates the structure of the network in terms of modules or communities. Higher values indicate a pronounced community structure. The decline in modularity from 2000 to 2024 might hint at a blurring of distinct collaborative communities over time, leading to a more integrated network.

Empirically, the collaboration network at the University of Stavanger has evolved in intriguing ways. While researchers were once more localized in their collaborations, the trend is now towards a more interconnected, cohesive community. However, the balance between highly collaborative scholars and those with fewer collaborations has remained relatively stable. This dynamic can be essential for fostering diverse interactions, where both experienced and emerging researchers bring unique perspectives to collaborative endeavors.

Table 4: UiS's collaboration network (individuals) - Advanced stats 1

Period	Cluster.coeff	Assortativity	Number.components	Share.larges.component	Modularity
Before 2000	0.33	-0.10	118	48	0.93
2000-2004	0.44	-0.07	70	50	0.93
2005-2009	0.37	-0.09	71	55	0.92
2010-2014	0.33	-0.13	71	77	0.90
2015-2019	0.28	-0.14	37	94	0.85
2020-2024	0.32	-0.06	53	88	0.80

Table 5 sheds light on the role the organizational structure of the university plays in the network and its development over time. More specifically, it assesses the degree to which scholars being part of the same department and faculty matters for their collaboration likelihood. Before the patterns are examined, the metrics presented in the table should be understood:

Faculties.per.cluster: By this measure, the average number of unique faculties involved in identified collaboration clusters is quantified. In the context of network analysis, a "cluster" typically refers to a group of nodes that are more densely connected to each other than they are to the rest of the network. In simple terms, it's akin to a tight-knit group of friends within a larger community. In the case of the University of Stavanger's collaboration network, these clusters represent groups of scholars who collaborate more frequently with each other than with researchers outside their cluster.[4] By comparing these clusters with the faculties to which scholars belong, one can derive further insights. For instance, a cluster predominantly consisting of researchers from a single faculty might suggest a strong tradition of intra-faculty collaboration. Conversely, a cluster comprising scholars from multiple faculties indicates interdisciplinary

[4]To identify these clusters within the network, the Louvain method of community detection was employed. This method iteratively groups nodes based on the strength and density of their connections, ensuring that the overall modularity of the network is optimized. Modularity, in this sense, quantifies the degree to which the network is compartmentalized into such clusters.

collaborations. A higher value indicates that more interdisciplinary interactions are being pursued.

Odd.within.faculty.link: By this metric, insight into the likelihood of collaboration between two scholars from the same faculty is provided. The intensity of collaboration within faculties is reflected by this measure whereby larger values imply a higher likelihood of a link being a connection between two researchers within the same faculty.

Odd.within.department.link: Similar to the previous metric, the likelihood of scholars from the same department collaborating is gauged. The depth of specialized collaborations is indicated by this measure. Larger values indicate that a collaboration between two researchers of the same department are more likely.

Table 5: UiS's collaboration network (individuals) - Advanced stats 2

Period	Faculties.per.cluster	Odd.within.faculty.link	Odd.within.department.link
Before 2000	2.59	0.94	0.92
2000-2004	2.80	3.97	4.16
2005-2009	3.12	4.83	5.18
2010-2014	3.52	16.93	36.01
2015-2019	3.96	19.24	30.30
2020-2024	4.26	18.81	40.62

With these metrics defined, it is observed that from *Before 2000* to *2020-2024*, a trend toward increased interdisciplinary collaboration is seen. This suggests that interdisciplinary research at the University of Stavanger is being embraced more widely, allowing for the inclusion of diverse expertise. However, alongside this trend, another pattern is noted: a significant rise in collaborations within faculties and departments. While the benefits of collaborations rooted in close academic or physical proximity, such as shared resources and deep expertise, are recognized, potential risks are also identified. Insularity, which can limit exposure to diverse research methodologies and fresh perspectives, might be inadvertently promoted. Furthermore, a reinforcement of existing beliefs, potentially at the expense of innovative thinking, could be facilitated by such concentrated collaborations.

In the grander scheme, the University of Stavanger's collaborative landscape is a blend of promising interdisciplinary endeavors and concentrated intra-departmental collaborations, managing a balancing act: while the depth and specialization achieved in focused collaborations are invaluable, it's equally vital to ensure that scholars have ample opportunities and incentives to venture beyond their immediate academic circles. Such a balance ensures that the research environment remains vibrant, innovative, and inclusive.

6.3 UiS's internal collaboration network at the level of departments

An alternative to looking at **UiS**'s internal collaboration network at the level of individuals is to aggregate it to the level of departments. That is, whenever scholars from two distinct departments collaborate the two departments' link will be strengthened. Figure 12 gives a graphical representation of this network for the period **2020-2024**. Each segment on the circle's perimeter represents an individual department, with its width reflecting the total number of collaborations that department engages in.

1 NettOp UiS
2 Dep.o.Academic Affairs
3 Section for Quality & Development in Education
4 Dep.o.Innovation & External Collaboration
5 Dep.o.Communication & Public Affairs
6 Dep.o.Facilities Management
7 HR department
8 Service Development Section
9 Dep.o.Corporate Governance & Development
10 Dep.o.Resources & Publishing
11 Dep.o.Research & Learning Support
12 Stavanger University Library
13 Research Department
14 Public Services
15 Norwegian Centre for Learning Environment & Behavi
16 Dep.o.Cultural Studies & Languages
17 National Centre for Reading Education & Research
18 Avdeling Porsgrunn
19 Dep.o.Education & Sports Science
20 Dep.o.Early Childhood Education
21 Faculty Administration UH
22 Kunnskapssenter for utdanning
23 Administration KSU
24 Administration SLF
25 Administrasjon NSLA Avd. Stavanger
26 Administrasjon NSLA Avd. Porsgrunn
27 Læringsmiljøsenteret – Porsgrunn
28 Department for national assignments
29 Avdeling Stavanger
30 Læringsmiljøsenteret – Administrasjon Stavanger
31 Dep.o.Quality & Health Technology
32 Dep.o.Public Health
33 Fakultetsadministrasjonen HV
34 Dep.o.Caring & Ethics
35 Avdeling for klassisk musikk
36 Avdeling for jazz, dans, PPU og musikkproduksjon
37 Fakultetsadministrasjonen UK
38 Dep.o.Mathematics & Physics
39 Dep.o.Safety, Economics & Planning
40 Dep.o.Chemistry, Bioscience & Environmental Engine
41 Dep.o.Energy Resources
42 Dep.o.Electrical Engineering & Computer Science
43 Dep.o.Energy & Petroleum Engineering
44 Laboratory IMBM
45 Dep.o.Mechanical & Structural Engineering & Materia
46 Laboratory IPT
47 Kontor for prosjektstøtte og ph.d.–administrasjon
48 Faculty Administration TN
49 Laboratory IMN
50 Laboratory IDE
51 Dep.o.Media & Social Sciences
52 Dep.o.Social Studies
53 Norwegian School of Hotel Management
54 Faculty Administration SV
55 Administration IS
56 Administrasjon IMS
57 Conservation
58 Communication
59 Artefacts
60 Collections
61 Museum Administration
62 HR department
63 Dep.o.Innovation, Management & Marketing
64 Dep.o.Economics & Finance
65 Dep.o.Accounting & Law
66 Fakultetsadministrasjonen HH–UIS

Figure 12: Network of departments

Chords (the colored links connecting the segments) symbolize collaborations between two departments. The broader a chord at its base, the more intense the collaboration, giving a direct visual cue about which departments work closely together. Departments with prominent arcs or segments are the hubs of collaboration, often taking the lead in inter-departmental research activities.

Table 6: Most intensively linked departments

Department1	Department2	Total_Count
Avdeling for jazz, dans, PPU og musikkproduksjon	Dep.o.Early Childhood Education	66
Dep.o.Public Health	Dep.o.Quality & Health Technology	50
Dep.o.Early Childhood Education	National Centre for Reading Education & Research	46
Dep.o.Caring & Ethics	Dep.o.Quality & Health Technology	41
Dep.o.Economics & Finance	Dep.o.Innovation, Management & Marketing	32
Dep.o.Quality & Health Technology	Fakultetsadministrasjonen HV	31

Table 6 lists the five strongest links between departments during this period. It is a mix of intra- and inter-faculty linkages indicating the previously discussed two-faced nature of collaboration at **UiS**: there are some very strong linkages across disciplines and faculties while simultaneously there are also very strong linkages that connect scholars operating in related fields.

The symmetry of the chords also tells a story. A chord that is uniform in width at both ends indicates mutual collaboration levels. In contrast, a disparity in width might suggest one department is more invested in or dependent on the partnership than the other. Table 7 reports the five strongest unsymmetrical relationships, i.e., links that represent a large portion of one department's total number of links but are relatively less important for the other department. Column *Department 1* features the departments for which the respective collaboration is relatively more important.

Table 7: Most unsymmetrical relationships

Department 1	Department 2	Asymmetry
Service Development Section	Dep.o.Electrical Engineering & Computer Science	0.99
Laboratory IDE	Dep.o.Electrical Engineering & Computer Science	0.99
Administration KSU	Kunnskapssenter for utdanning	0.97
Fakultetsadministrasjonen HH-UIS	Dep.o.Innovation, Management & Marketing	0.96
Laboratory IMN	Dep.o.Chemistry, Bioscience & Environmental Engineering	0.94

It becomes clear that departments differ greatly in their intensity of university internal collaboration. In this context, it is interesting to identify those departments that are able to bridge different parts of the university's collaboration network. Imagine the University of Stavanger as a vast city, where each department is a landmark or destination. The collaborations between these departments are the roads connecting them. In this city, scholars often travel between these landmarks, but they prefer to take the shortest route to save time and effort.

Now, the concept of the *shortest path* in network analysis is similar to finding the quickest (shortest) route between two landmarks in our city analogy. It is the path that requires the least number of roads (or collaborations) to go from one destination (department) to another.

This is where *betweenness centrality* comes in. Betweenness centrality highlights the importance of certain landmarks in our city analogy. Imagine some landmarks find themselves frequently along the quickest routes between many other

pairs of points of interest. Think of these landmarks as crucial intersections (e.g., the main train station) in the city—places where many roads converge, and which travelers often pass through to efficiently reach their destinations. A department with high betweenness centrality is like a major intersection in the city. It lies on many shortest paths, indicating its pivotal role in connecting different parts of the city (or, in our scenario, the university's collaboration network).

In simpler terms, a department with high betweenness centrality often lies on the most efficient collaboration routes between other departments. This implies that such a department not only collaborates extensively but also is vital in fostering connections and the spread of knowledge among various departments. By virtue of its central position, it gets exposed to a myriad of ideas, research methods, and academic perspectives. This makes it a potential hub of interdisciplinary knowledge at the University of Stavanger.

Table 8: Spider departments

Period	Rank.1	Rank.2	Rank.3
Before 2000	Dep.o.Media & Social Sciences	Dep.o.Safety, Economics & Planning	Norwegian School of Hotel Management
2000-2004	Dep.o.Media & Social Sciences	Dep.o.Social Studies	Norwegian Centre for Learning Environment & Behavioral Research in Education
2005-2009	Dep.o.Media & Social Sciences	Dep.o.Mathematics & Physics	Dep.o.Safety, Economics & Planning
2010-2014	Dep.o.Media & Social Sciences	Dep.o.Energy & Petroleum Engineering	Dep.o.Education & Sports Science
2015-2019	Dep.o.Media & Social Sciences	Dep.o.Education & Sports Science	Dep.o.Social Studies
2020-2024	Dep.o.Early Childhood Education	Norwegian Centre for Learning Environment & Behavioral Research in Education	Dep.o.Chemistry, Bioscience & Environmental Engineering

For the University of Stavanger, recognizing such departments provides valuable insights. After all, these central departments play a significant role in knitting together the university's rich tapestry of research, learning, and innovation. Table 8 lists the three departments with the highest value of betweenness centrality in each period. These departments have, more than others, acted as connectors and knowledge diffusion hubs within the university.They may have obtained their role by being more active in terms of inter-department collaborations than others, by being larger and, therefore, having a greater capacity to engage in such activities, or because their research focus is more suitable for interdisciplinary work. Whatever the reason, in the most recent period **2020-2024** it was the Dep.o.Early Childhood Education and the Norwegian Centre for Learning Environment & Behavioral Research in Education that established the most bridges and acted as spiders in the web of the university's internal collaboration network.

7 UiS and sustainability related research

In today's rapidly evolving global landscape, the United Nations' Sustainable Development Goals serve as a beacon, guiding societies towards a future that is environmentally responsible, socially equitable, and economically viable. For institutions of higher learning like the University of Stavanger, their research activities hold immense potential to shape societal progress. When the university's research aligns with the UN's Sustainability Goals, it signifies a commitment to addressing some of the most pressing challenges of our time. From climate change and biodiversity loss to social inequality and economic disparities, these goals encompass a wide range of issues that are critical to our planet's health and humanity's well-being.

By analyzing the research landscape of the University of Stavanger and how and where it relates to the UN's Sustainability Goals, the institution's contribution to this global mission was assessed. This provides insights into the areas where the university is already making impactful strides but also those domains that might benefit from increased attention. Moreover, such an analysis underscores the university's role in advancing knowledge that is not only academically commendable but also socially relevant and urgently needed.

7.1 Methodological explainations

To determine which research items are aligned with the SDGs, the text of these articles needed to be analyzed. Where available, the titles, keywords, and abstracts of the research items were evaluated to identify potential links to the SDGs, which are defined through textual descriptors. It has been noted that research from the University of Stavanger is presented in multiple languages, see **Section 4** with Norwegian and English being the most widely used. To ensure a thorough and accurate analysis, only the research items published in English (as indicated in the **Cristin** database) will be considered in the following sections. This reduces the number of unique research items considered from 74,725 to 31,430.

The word cloud displayed in Figure 13 visualizes the heterogeneity of research topics in the focus of **UiS**'s scholars, as well as their evolution over time. The cloud is based on keywords associated with research items in the **Cristin** database and enriched by information from **Scopus**, (see Enriching the data with Scopus). Each corner represents one of the most recent time periods and the most prominent keywords for research of that period. In this word cloud, the size of each word indicates its relative frequency. Larger words appeared more often in the texts for a given period compared to the smaller words. The word cloud is a comparative one, meaning that words which are distinctive to each period are emphasized, allowing to see how word prominence shifts over time.

While the figure highlights the importance of health-related research throughout the considered time periods and at the same time visualizes the emergence of new topics, such as **Covid**, it just provides a general insight into the type of textual information available as well as general topics scholars work on. A more detailed approach is necessary for identifying links to the SDGs.

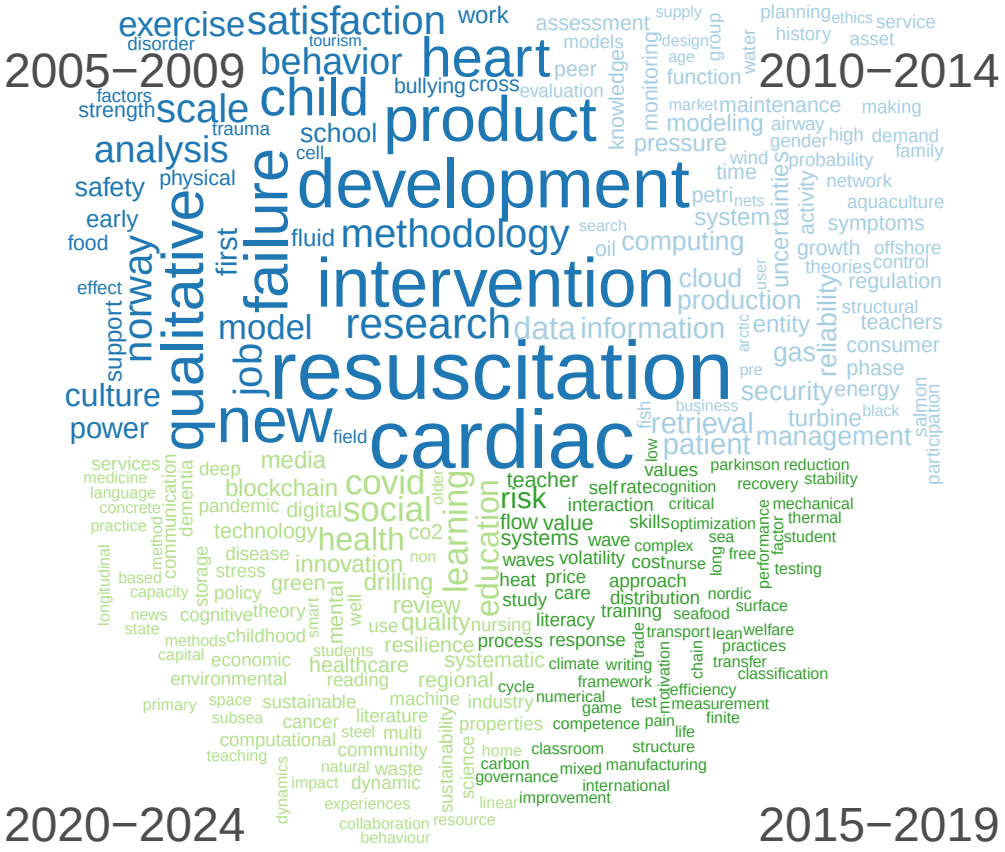

Figure 13: Keywords of research output

7.2 Identification of SDGs in text data

Linking the research output to the SDGs was done using the **text2sdg** package in **R**, which is designed to detect references to the United Nations' Sustainable Development Goals (SDGs) within textual data. A notable feature of it is its dictionary, which forms the basis for detecting these references. This dictionary is constructed meticulously from the official documentation and descriptions of the SDGs provided by the United Nations. These official documents not only present the overarching goals but also delve deep into the targets and indicators associated with each SDG (see for details, Meier et al., 2021).

To create a comprehensive and effective dictionary, researchers and developers of the package undertook an extensive review of these UN documents. They extracted keywords, phrases, and terms that encapsulated the essence of each goal. This initial extraction was the starting point, but the dictionary's refinement didn't stop there. It was further validated by testing its performance on known data sets and texts that had explicit references to the SDGs. This iterative process of testing and refining ensured that the dictionary was both sensitive (capturing genuine SDG references) and specific (minimizing false positives) (Meier et al., 2021). The decision to root the dictionary in official UN documents was a deliberate one. It ensures that any detected references in textual data are genuinely aligned with the United Nations' own understandings and definitions of each SDG.

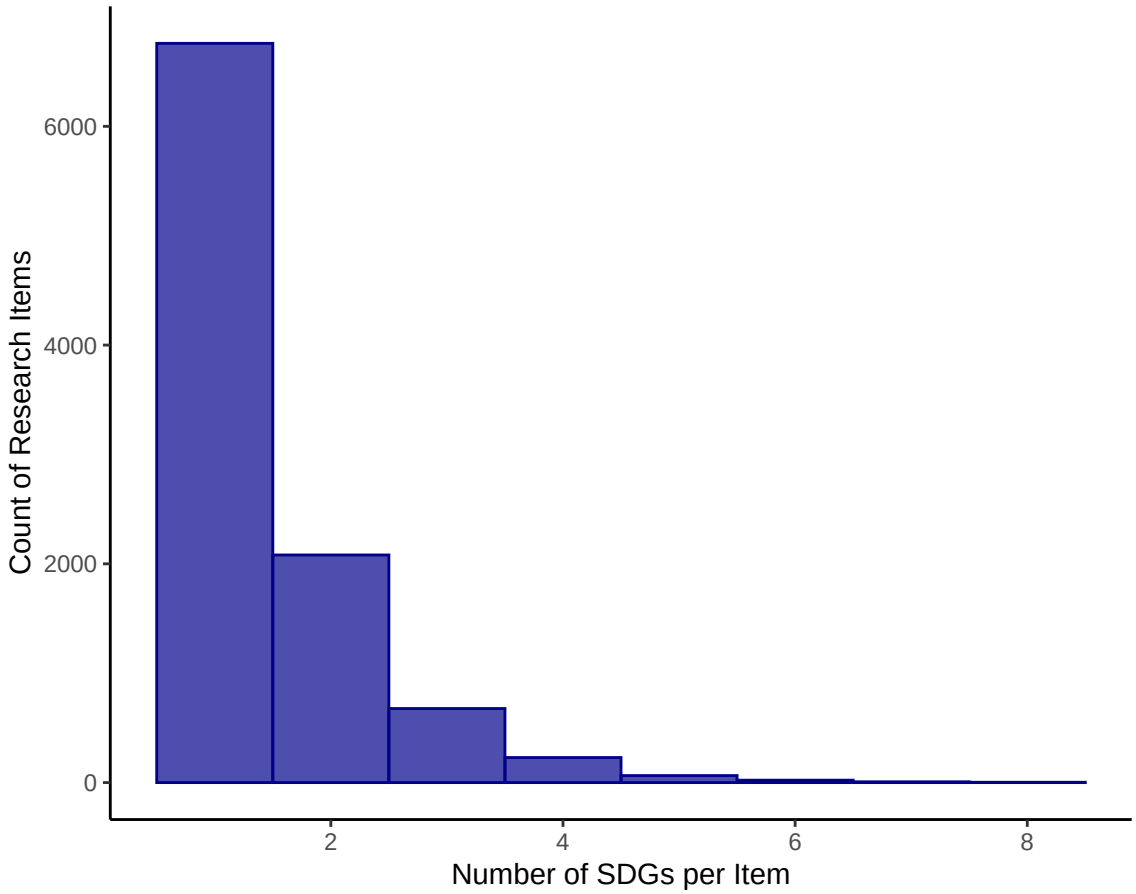

Figure 14: Histogram of SDGs per item

The identification of **UiS** output was done considering research items' titles, keywords, and abstracts. For each item in the **Cristin** database registered with *English* as original language, the procedure checked if any of its words/tokens correspond to those of the SDGs and in case of a match, assigns the corresponding SDG to the research item. The procedure allowed for an item to be associated to multiple SDGs. About 31% of all items were associated to more than one SDG. The distribution of the number of SDGs per research item is depicted in Figure 14.

7.3 UiS's contribution to SDG-related research

Equipped with this information, the share of research output that can be associated to at least one SDG for the University of Stavanger is calculated for each year and plotted in Figure 15. The light blue dots represent the values for the individual years and the dark blue line the non-linear trend regression. Clearly, researchers at the university have recognized the need to contribute to a more sustainable future. The share of their research output that can be linked to at least one SDG has grown from 21% in 1996 to about 41% in 2022. Over the years, there's been a consistent upward trend, hinting at a potential future increase in the share. However, from 2020 onwards, the share appears to hover around 40%. While it is too early to conclude that the progress has plateaued, the once rapid, almost exponential growth seems to have slowed down. If the goal is to boost the share of SDG-related research, the possibility of a leveling off indicates the need to intensify efforts and address this perceived saturation.

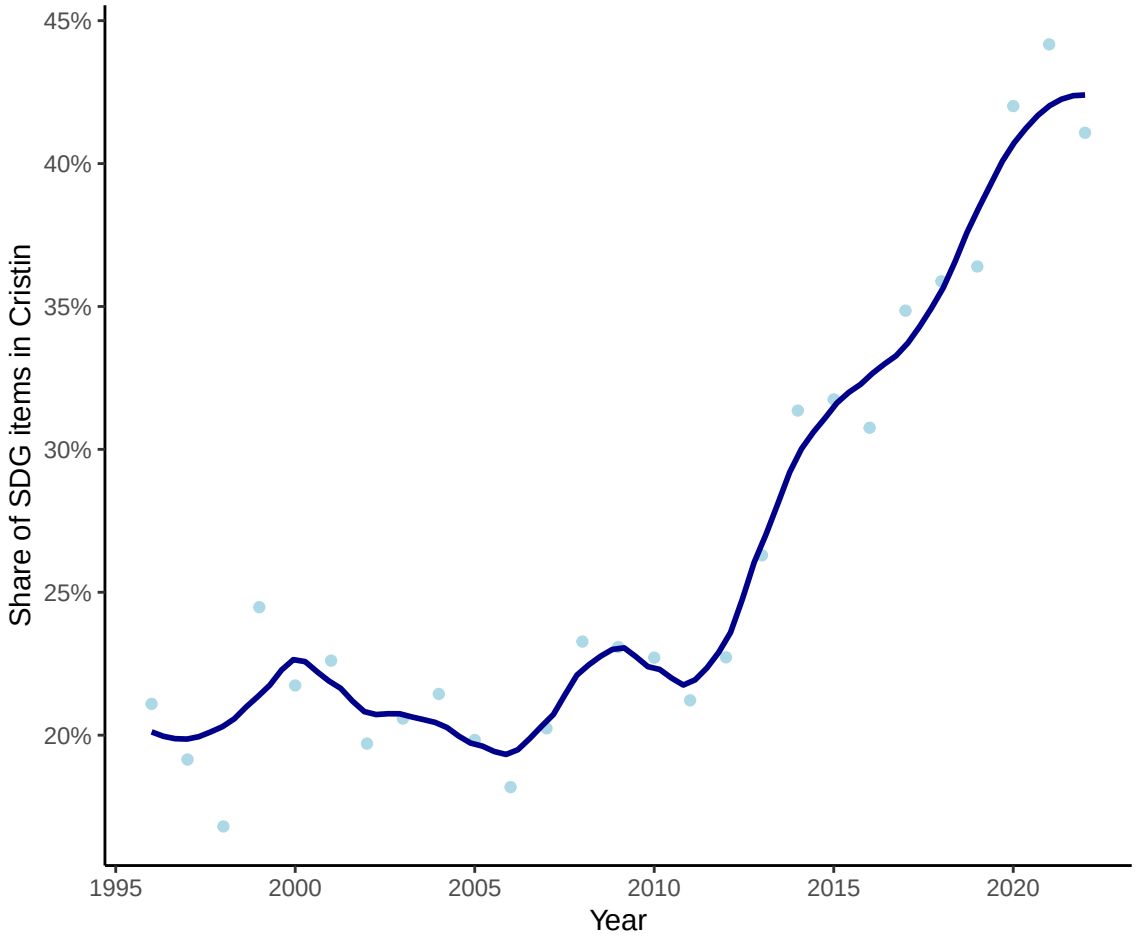

Figure 15: Share of SDG-related research

When examining Figure 15, it is important to keep in mind the type of textual information on hand as it plays a pivotal role in identifying SDGs. For instance, titles generally offer less scope for detecting SDG-related keywords compared to abstracts and keywords, which inherently carry more detailed information. It's also noteworthy that while every item in the database has a title, many are devoid of abstracts or keywords. This absence could either be due to the original **Cristin** entry not providing them, or a mismatch when aligning with the Scopus database. To provide some perspective, only about 23% of all English entries come with an abstract, and the figure drops further to 18% with regards to keywords.

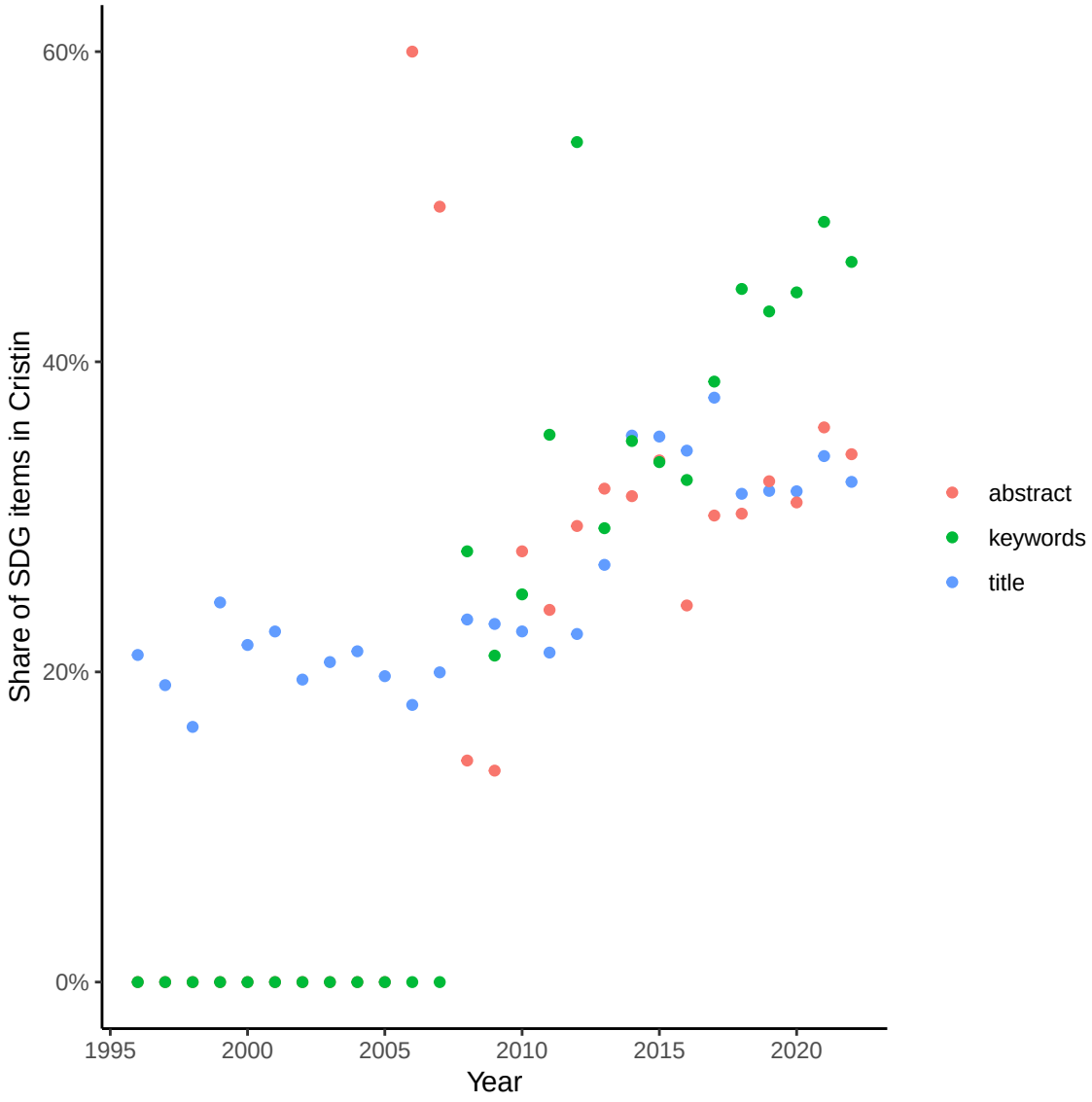

Figure 16: Identification of SDGs in abstract, title, or keywords

Figure 16 breaks down the percentages of items linked to SDGs, categorizing them based on the availability of abstracts (abstract), keywords (keywords), or just titles (title). Each dot in the figure represents the percentage of items with abstracts, keywords, and/or titles that can be associated to at least one SDG per year. For instance, in 2022, at least one SDG is identified for 34.04% of all items with an abstract. An intriguing observation from recent years is the minimal difference in SDG identification between items with only titles and those with abstracts.

In contrast, the presence of keywords significantly boosts the chances of pinpointing at least one SDG. This heightened likelihood with keywords may be due to the deliberate and perhaps more strategic selection of these terms by researchers.

7.4 UiS faculties' contribution to SDG-related research

The University of Stavanger has been actively contributing to research associated with the Sustainable Development Goals (SDGs). Nonetheless, certain variations exist between its faculties, which will be evaluated below. Figure 17

illustrates the distribution of SDG-related research within each faculty and over time.

For instance, in 2022, the *Faculty of Health Sciences* had approximately 55.43% (199 out of 359) of its publications being SDG-related. In contrast, the *Faculty of Arts & Education* had 203 out of its 551 publications related to SDGs, accounting for about 36.84% of its research output for the same year. This variance underscores the differential emphasis and alignment of various faculties with the SDGs.

It's essential to take note of faculties that consistently rank high in terms of the share of SDG-related research. Such faculties may have strategic interests or strengths in areas that naturally align with the SDGs. But on the other hand, faculties with a lower share might be focusing on equally important areas of research that may not directly correspond to the SDGs.

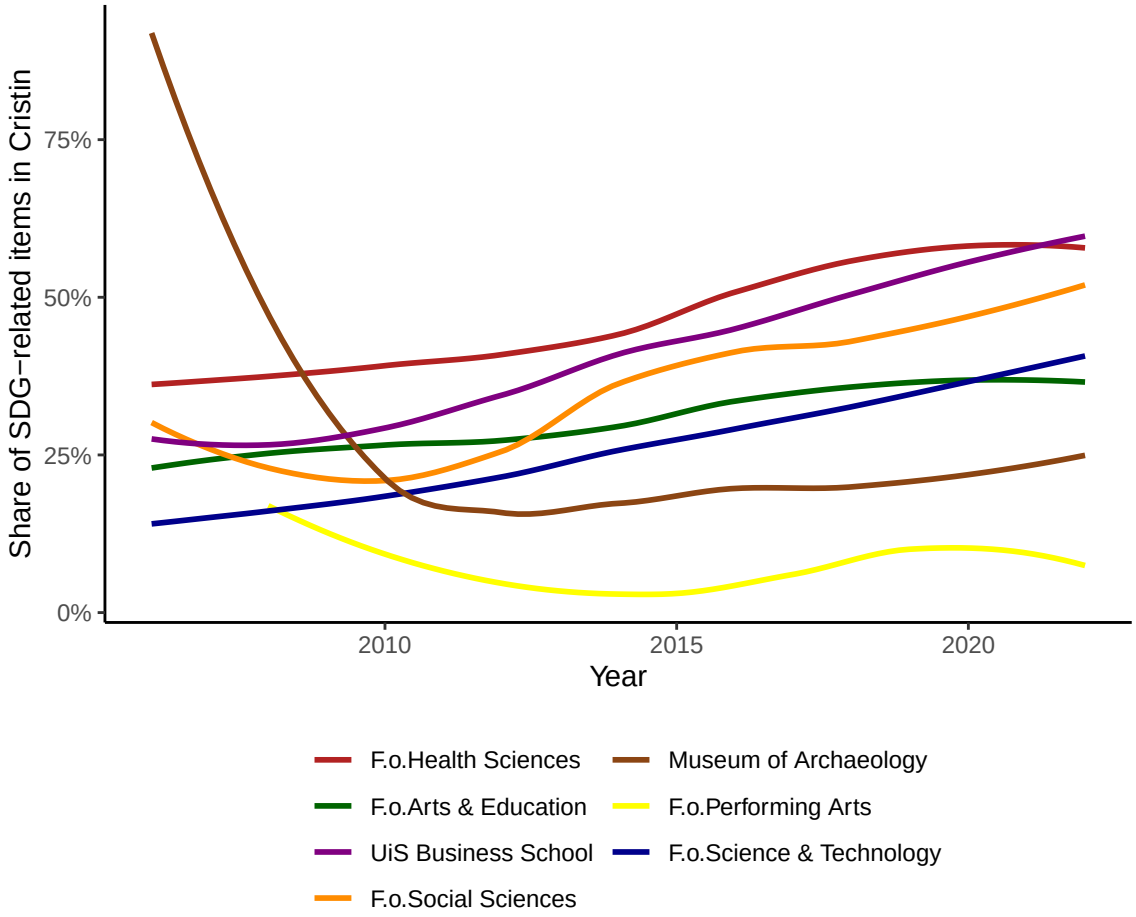

Figure 17: Faculties' contribution to SDG-related research

The number of publications may also play a role in this. As for another example in 2022, the *Faculty of Science & Technology* had 1051 publications, of which 39.2% were related to the SDGs. In contrast, the *UiS Business School* with only a third as many publications (265) as the *Faculty of Science & Technology*, accomplished a much higher share at 55.85%. Hence, the size of faculties does not seem to be an important factor here, which is confirmed by the correlation between the number of publications per year and the share of SDG-related research of only r=0.14.

In recent years, it is worth observing if there are any shifts in these patterns, indicating a change in research focus or alignment with the SDGs. Some faculties appear to be steadily increasing their shares, while others may have reached

a plateau in their contributions. This might be due to general misalignment of research fields with the keywords used in the SDG identification. However, it might also indicate a lack of incentives and support for such type of research. Consequently, it is essential to provide a continuous monitoring of these shares, as this provides valuable insights for the university to assess its contribution towards global sustainable goals and to strategically plan future research directions.

7.5 Contributions to individual SDGs

There is not only heterogeneity in the degree particular faculties contribute research to the SDGs. In addition, the contribution varies across the seventeen SDGs. Using the matched research items to SDGs data set, the emphasis placed on each SDG over the years can be quantified, with data from 2022 being the most recent. Two figures are provided. Figure 18 depicts a snapshot of the year 2022 and presents the relative shares of research attributed to individual SDGs as pie chart. In contrast, Figure 19 visualizes the development and potential shifts in the relative importance of individual SDGs over time by plotting the annual numbers of research items associated with an SDG over time as stacked-area plot.

Figure 18 highlights that SDG-03 Good Health and Well-being in particular, has the most research output in 2022, with 288 publications at UiS.

Following closely, SDG-09 Industry, Innovation and Infrastructure and SDG-07 Affordable and Clean Energy indicate the breadth of research focus at the university. These SDGs have 261 and 170 associated research items respectively in 2022, highlighting their continued relevance in academic discussions.

Figure 19 visualizes the previously identified noticeable growth in the number of research items related to all SDGs at the University of Stavanger. This serves as an indicator of increasing global importance and awareness of these goals. More importantly, it also shows that certain SDGs have seen a remarkable increase in research output over the years, emphasizing the growing interest in these areas. On the other hand, while many SDGs witness a surge in research, some exhibit a steadying or even a marginal decline. Recognizing these patterns is essential to ensure alignment with both global and institutional priorities.

SDG-08 Decent Work and Economic Growth has seen a significant increase in research output over the years, with its publication count growing by approximately 60.22% on average year-to-year since its first year of recording. Another SDG that has caught rising interest from **UiS** researchers is SDG-17 Partnerships to achieve the Goal, which has grown by about 43.9% on average year-to-year over the same period.

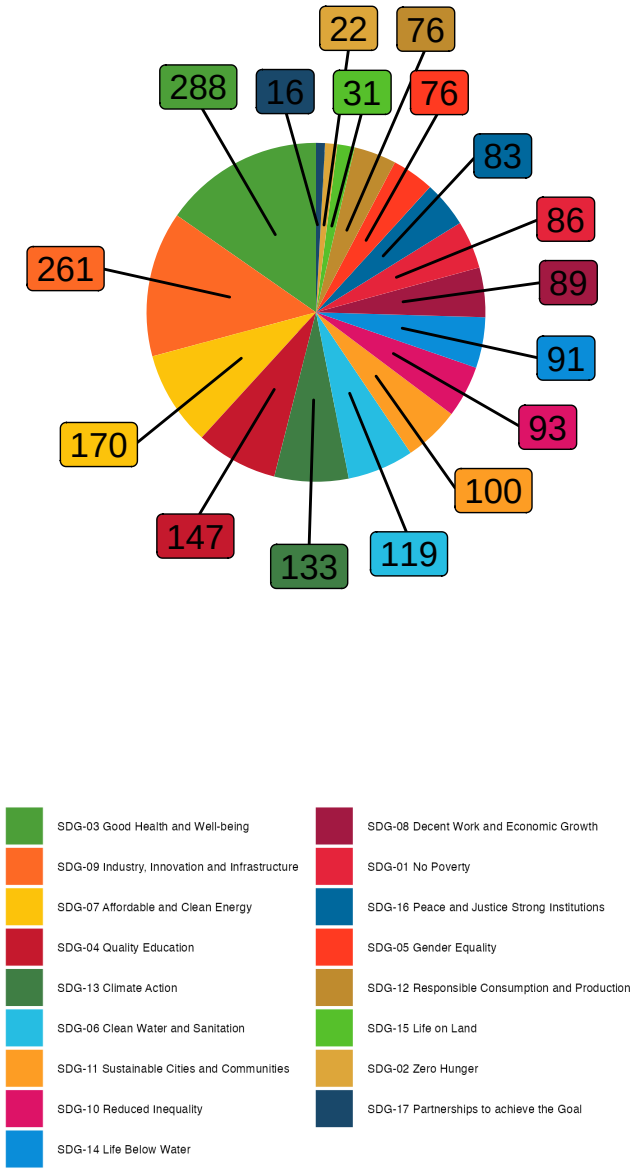

Figure 18: UiS's contribution to individual SDGs in 2022

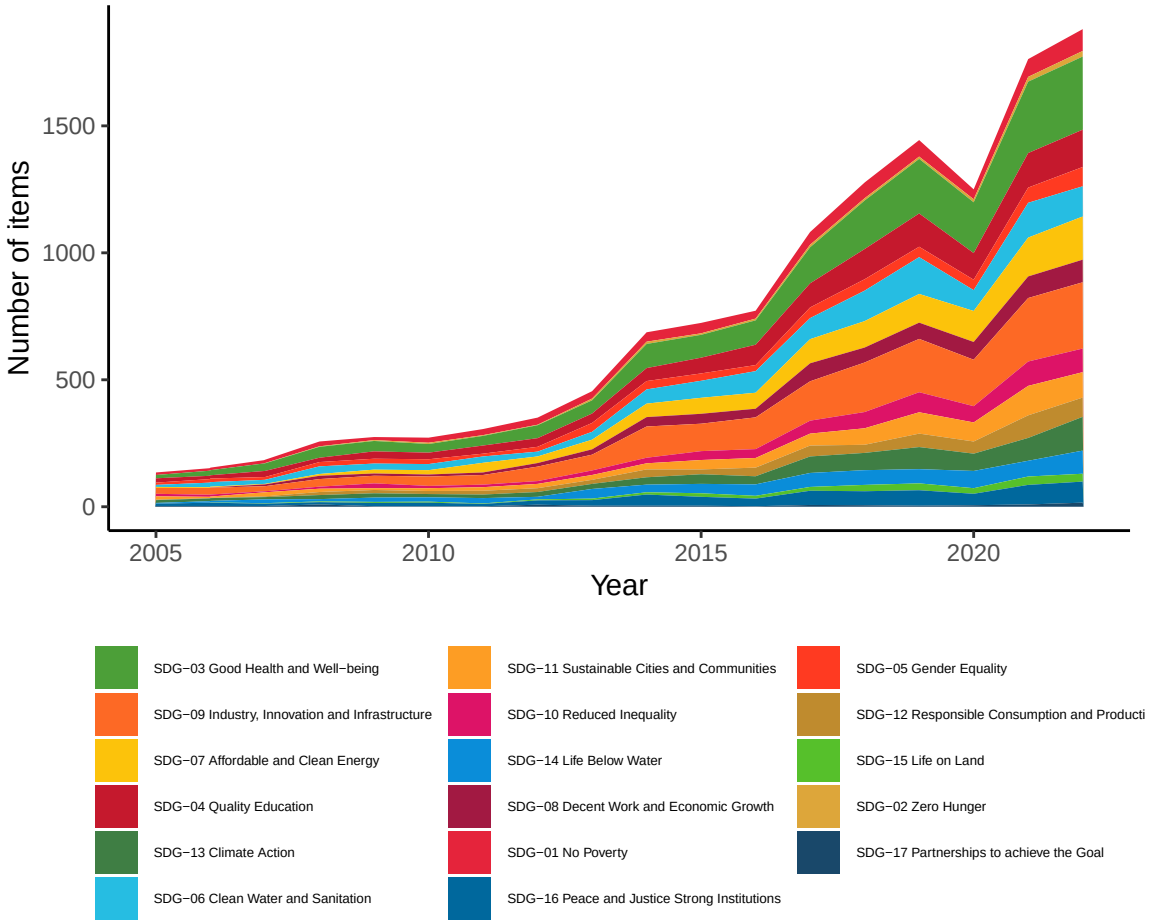

Figure 19: UiS's contribution to individual SDGs over time

On the other hand, while the absolute numbers for most SDGs have increased, the growth rate for some has either steadied or marginally declined. For instance, the research output for SDG SDG-04 Quality Education has seen a growth of just 17.09% year-to-year on average since its first year.

These shifts in research focus underscore the dynamic nature of academic interests and priorities. Recognizing and understanding these patterns is crucial for the University of Stavanger, ensuring that its research remains aligned with both global challenges and institutional goals. In addition, it is essential to evaluate if the contributions to individual SDGs align with the desired overarching priorities and image of the institution. Figure 20 gives a final visualization of the changing relative importance of the SDGs in scholars' research output at the University of Stavanger.

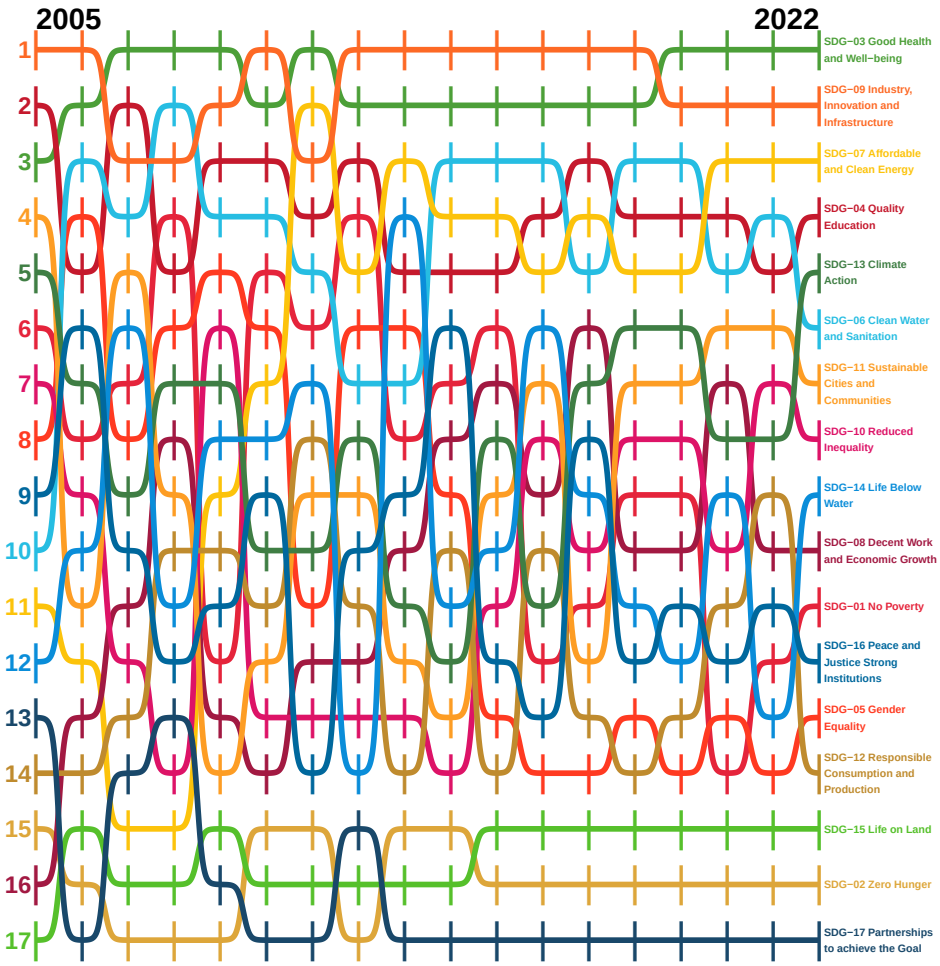

Figure 20: Rank by number of Cristin items from 2005 to 2022

8 SDGs and UiS's internal collaboration

In earlier sections, collaboration and sustainability were addressed as distinct dimensions. This segment aims to intertwine the two, probing the extent to which collaboration and the internal knowledge network at **UiS** bolster research related to the Sustainable Development Goals (SDGs). The main objective is to determine whether research items, originating from different collaborative frameworks, demonstrate a greater association with any of the SDGs.

This exploration leverages the data set of **Cristin** items drafted in English, segmenting them based on their production timelines. The periods examined include again *Before 2000*, *2000-2004*, *2005-2009*, *2010-2014*, *2015-2019*, and *2020-2024*, with each time frame analysed separately to provide a comprehensive understanding of temporal changes.

To begin, for each period all items were divided into two groups: on the one hand all items that can be associated with at least one SDG, and on the other all that cannot. For the two groups, a number of metrics were calculated describing different dimensions of the (potentially) underlying collaborative efforts. The following metrics are considered.

SAME.DEP: Represents the collaborations that occur within the same academic department. That is, it measures if the focal research item involves a collaboration with another researcher from the same department, which usually implies a relatively low level of inter-disciplinarity.

SAME.FAC.OTH.DEP: Denotes collaborations that take place within the same faculty, yet outside the primary department of the researcher. This type of collaboration has a higher degree of inter-disciplinarity than **SAME.DEP**.

OTHER.FAC: Refers to the collaborations that span across different faculties of the university. Here, it represents the strongest indication of the creation of a research item being characterized by inter-disciplinarity.

CONTR: Signifies the total number of contributors involved in a particular research item. The larger this number, the more scholars have contributed to an item. Put differently, a large value of this variable characterizes collaborative research.

CUM.ITEM: Captures the cumulative count of research items authored or co-authored by a researcher up to the current period. It can be seen as a measure of the researcher's seniority.

ITEMS: Denotes the overall number of research items a scholar has contributed to during the focal period. It approximates the researcher's productivity.

BETWEEN: Represents the betweenness centrality of a scholar in the collaboration network, indicating their role as a bridge or connector within the network.

SHARE.CUM.SDG: stands for the fraction of a researcher's cumulative research, up to a specific epoch, that resonates with at least one SDG.

In this report, it is sought to determine whether items associated with at least one SDG were meaningfully different from those without any SDG association. To ensure comprehensive examination, a multivariate regression framework was employed. This method was chosen to prevent potential misinterpretations where differences attributed to one metric might be influenced by another. For instance, items that were produced from collaborations with multiple partners might inherently involve individuals from different departments.

To account for such intertwined factors, logistic regression was used. This allows items to be compared across various metrics, differentiating between those with an SDG association and those without. The findings revealed that items associated with an SDG typically registered either higher or lower values in specific metrics. In the context of this report, it was assumed that the metrics represent causal factors. Thereby, the results can be interpreted as follows: a positive coefficient suggests that an increased intensity of a specific factor enhances the likelihood of a research output contributing to any of the SDGs.

The variable **SAME.DEP**, representing collaborations within the same department, initially exhibited a fluctuating relationship with SDG-related research. However, from *2010-2014* onward, a discernible trend emerged, where such collaborations were slightly less likely to produce SDG-related research, a trend that has persisted into the *2020-2024* period. Accordingly, SDG-related research is facilitated by collaborating researchers having a certain degree of inter-disciplinarity, i.e., collaboration involving contributors with diverse backgrounds.

Collaborations within the same faculty but across different departments, denoted as **SAME.FAC.OTH.DEP**, showed a decreasing likelihood of SDG alignment from *2010-2014* onward. This trend was particularly evident in the *2020-2024* bracket, further solidifying the pattern. Hence, collaborations within the same faculty tend to lack the diversity and inter-disciplinarity required to promote SDG-related research.

Inter-faculty collaborations, symbolized by **OTHER.FAC**, have emerged as a consistent and robust driver for SDG-related research. This link has not only been evident but has sustained its potency across all examined time frames. Notably, the most recent period, *2020-2024*, reaffirms this association with an odds ratio of 1.015. This pattern accentuates the earlier insights, clearly indicating the catalytic role of interdisciplinary approaches on advancing research

	Before 2000	2000-2004	2005-2009	2010-2014	2015-2019	2020-2024
ITEMS	1.000	1.000	1.000	0.999*	0.999***	0.999***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
BETWEEN	1.000	1.000	1.000	0.999*	1.000	1.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SAME.DEP	0.994	0.996	0.983	0.961*	0.970*	0.955**
	(0.032)	(0.032)	(0.016)	(0.020)	(0.017)	(0.019)
SAME.FAC.OTH.DEP	1.136	0.958	1.000	0.866**	1.087**	1.005
	(0.183)	(0.076)	(0.091)	(0.066)	(0.052)	(0.031)
OTHER.FAC	1.018	1.010	0.978	1.112*	0.950	1.015
	(0.035)	(0.028)	(0.036)	(0.069)	(0.047)	(0.070)
CONTR	1.006	1.006	0.999	1.004	1.008***	1.004***
	(0.004)	(0.007)	(0.004)	(0.003)	(0.003)	(0.001)
SHARE.CUM.SDG	2.706***	2.698***	2.723***	2.739***	2.729***	2.605***
	(0.015)	(0.030)	(0.027)	(0.023)	(0.040)	(0.052)
CUM.ITEM		1.000	1.000	1.000***	1.000***	1.001***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FE	Year	Year	Year	Year	Year	Year
FE	Dep.	Dep.	Dep.	Dep.	Dep.	Dep.
Robust std.err	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.476	0.374	0.326	0.277	0.261	0.220
Adj. R^2	0.469	0.365	0.322	0.272	0.258	0.217
Num. obs.	2807	2868	6013	8705	15977	12051

$^{***}p < 0.001; ^{**}p < 0.01; ^{*}p < 0.05$

Table 9: Statistical models

centred on SDGs. Interestingly, the interdisciplinarity at **UiS** is distinguished by collaborations across various faculties, rather than being restricted within singular faculties or departments. This distinction is pivotal, especially when considering the prevailing collaboration dynamics at **UiS**. As detailed in **Section 5.1**, inter-faculty collaborations remain a less trodden path at **UiS**. Recognizing its potential as a potent catalyst for SDG-driven research provides a compelling rationale for **UiS** to pivot towards nurturing and incentivizing such collaborative frameworks, thereby amplifying the institution's contribution to global sustainability goals.

The **BETWEEN** variable, which emphasizes researchers occupying central positions in collaborative networks, has invariably shown an affinity towards SDG-focused research across all the evaluated time spans. Its significance resonates especially in the latest *2020-2024* period, underscoring a sustained trend. This metric essentially encapsulates the pivotal role of individuals who are skilled at linking different segments of **UiS**'s internal collaboration network, thus creating bridges of knowledge. Such a trend can be interpreted in dual ways: a) it may reflect the inherent nature of SDG-aligned research, which demands access to a broad spectrum of knowledge, or b) it hints at those individuals at the nexus of the **UiS** collaboration network having a profound commitment to SDG-centric research. Regardless of the specific interpretation, the overall implication is evident - the structural intricacies of the knowledge network and the researchers' relative positions within it hold significant influence over the path of SDG-aligned academic endeavours.

CONTR, reflecting the magnitude of individual contributions, has consistently shown a robust positive association with SDG alignment across all periods, underscoring the importance of individual academic contributions in shaping research direction. In addition, it suggests that more productive (in terms of producing more research items in the focal period) individuals are more likely to make contributions to SDG-related research.

The incorporation of **SHARE.CUM.SDG** sheds light on the percentage of a researcher's accumulative SDG-oriented work up to the present period. A pronounced positive relationship was discerned, with the *2020-2024* period standing out particularly. The significant coefficient underscores that researchers with a substantial fraction of their prior research linked to any SDG are predisposed to sustain such research endeavors in subsequent periods.Two predominant dynamics might explain this behavior. The first pertains to the learning curve. Engaging in SDG-related research often requires acquiring a specific set of skills and insights. Once these researchers have cultivated these competencies, it

becomes both efficient and intuitive for them to apply these capabilities in subsequent research, thereby consistently producing SDG-aligned contributions (Lave & Wenger, 1991). The second dynamic revolves around the principle of path dependency, a concept rooted in the historical institutionalism theory (Pierson, 2000). Once researchers have ventured into SDG-centric domains, they often find themselves on a distinct research trajectory shaped by prior choices and investments. This trajectory, in turn, exerts a powerful influence, making it less likely for them to deviate significantly in subsequent research endeavors. This path-dependent behavior stems from a combination of institutional pressures, cognitive routines, and the cumulative nature of knowledge, which together reinforce the continuation along a pre-established research path (Arthur, 1994; David, 1985). In essence, both the learning mechanisms and path dependency underscore the cumulative and often self-reinforcing nature of research choices, especially when it comes to areas as multidimensional and impactful as the SDGs.

Through this intricate exploration, the study sheds light on the symbiotic relationship between academic collaboration patterns at **UiS** and alignment with the SDGs. Such insights are invaluable for academic institutions and researchers, channeling collaborative endeavors towards resonating more profoundly with global sustainability objectives.

9 Conclusion

The primary aim of this report was to illuminate the intricate landscape of research collaboration at the University of Stavanger and its alignment with the United Nations' Sustainable Development Goals (SDGs). Employing the Cristin database as its backbone, the investigation offered a detailed view of **UiS**'s academic activities, revealing pivotal trends, patterns, and dynamics.

A significant change was noted in collaborations, with a surge in those involving researchers from outside of **UiS**, indicating a growing international research environment. Collaborations within **UiS** predominantly thrived within individual departments, highlighting the interdependent and cooperative nature of these research communities. However, broader interdisciplinary collaborations, especially those spanning across faculties, were relatively infrequent, indicating untapped potential for such endeavors.

The topographical evolution of **UiS**'s internal collaboration network provided deeper insights into its structure and dynamics. From its early days of isolated clusters, the network has matured into a more integrated and complex entity. Central nodes or 'hubs' emerged as critical elements, bridging various clusters and facilitating knowledge flow. Over time, a shift was evident towards a more interconnected research ecosystem at **UiS**, even though certain foundational characteristics, rooted in departmental or faculty affiliations, persisted.

Exploring the SDGs, a clear linkage between collaborative nature and SDG alignment was discerned. Interdisciplinary collaborations were particularly influential in producing research outputs resonating with SDGs. Additionally, the strategic positions of researchers within the network, especially those in central or bridging roles, were instrumental in shaping **UiS**'s contributions to the SDGs.

Furthermore, a transformation in the language preference for research outputs was identified. English has progressively become the dominant medium, reflecting global academic trends and emphasizing **UiS**'s aspiration for broader international resonance.

In synthesis, this report has unveiled the multifaceted dynamics governing **UiS**'s research collaborations and their resonance with global sustainability goals. It underscores the potential for further fostering interdisciplinary research and highlights the pivotal roles of individual researchers in this endeavor.

References

Arthur, W. B. (1994). *Increasing Returns and Path Dependence in the Economy*. University of Michigan Press.

Barabasi, A., Jeong, H., Neda, Z., Ravasz, E., Schubert, A., & Vicsek, T. (2002). Evolution of the social network of scientific collaborations. *Physica*, *A 311*(3–4), 590–614.

Boschma, R. A., & ter Wal, A. L. J. (2007). Knowledge networks and innovative performance in an industrial district: The case of a footwear district in the south of Italy. *Industry and Innovation*, *14*(2), 177–199. https://doi.org/10.1080/13662710701253441

Broekel, T., & Mueller, W. (2018). Critical links in knowledge networks – What about proximities and gatekeeper organisations? *Industry and Innovation*, *10*(1), 919–339. https://doi.org/10.1080/13662716.2017.1343130

Burt, R. S. (1992). *Structural holes: The social structure of competition*. Harvard University Press.

Cottafava, D., Ascione, G. S., Corazza, L., & Dhir, A. (2022). Sustainable development goals research in higher education institutions: An interdisciplinarity assessment through an entropy-based indicator. *Journal of Business Research*, *151*, 138–155. https://doi.org/10.1016/j.jbusres.2022.06.050

David, P. A. (1985). Clio and the Economics of QWERTY. *American Economic Review*, *75*(2), 332–.

DiVito, L., van Wijk, J., & Wakkee, I. (2021). Governing Collaborative Value Creation in the Context of Grand Challenges: A Case Study of a Cross-Sectoral Collaboration in the Textile Industry. *Business and Society*, *60*(5), 1092–1131. https://doi.org/10.1177/0007650320930657

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations. *Research Policy*, *29*(2), 109–123. http://www.sciencedirect.com/science/article/B6V77-3YTBY18-1/2/ab127cd03fde732424995b91cd0cba1e

Freeman, L. C. (1978). Centrality in Social Networks Conceptual Clarification. *Matrix*, *1*(1968), 215–239.

Harzing, A.-W., & Alakangas, S. (2016). Google Scholar, Scopus and the Web of Science: a longitudinal and cross-disciplinary comparison. *Scientometrics*, *106*(2), 787–804. https://doi.org/10.1007/s11192-015-1798-9

Kobarg, S., Stumpf-Wollersheim, J., Schlägel, C., & Welpe, I. M. (2020). Green together? The effects of companies' innovation collaboration with different partner types on ecological process and product innovation. *Industry and Innovation*, *27*(9), 953–990. https://doi.org/10.1080/13662716.2020.1713733

Lave, J., & Wenger, E. (1991). *Situated Learning*. Cambridge University Press. https://doi.org/10.1017/CBO9780511815355

Meier, D. S., Mata, R., & Wulff, D. U. (2021). text2sdg: An R package to Monitor Sustainable Development Goals from Text. *20*, 1–10. http://arxiv.org/abs/2110.05856

Pierson, P. (2000). Increasing Returns, Path Dependence, and the Study of Politics. *American Political Science Review*, *94*(2), 251–267. https://doi.org/10.2307/2586011

Pudelko, M., & Tenzer, H. (2019). Boundaryless Careers or Career Boundaries? The Impact of Language Barriers on Academic Careers in International Business Schools. *Academy of Management Learning & Education*, *18*(2), 213–240. https://doi.org/10.5465/amle.2017.0236

Thingnes, J. S. (2020). Making linguistic choices at a Sámi University: negotiating visions and demands. *Current Issues in Language Planning*, *21*(2), 153–174. https://doi.org/10.1080/14664208.2019.1671712

Uzzi, B. (1996). The sources and consequences of embeddedness for the economic performance of organizations: the network effect. *American Sociological Review*, *61*(4), 674–698.

Uzzi, B. (1997). Social structure and competition in interfirm networks: the paradox of embeddedness. *Administrative Science Quarterly*, *42*(1), 35–67.

van Zanten, J. A., & van Tulder, R. (2021). Analyzing companies' interactions with the Sustainable Development Goals through network analysis: Four corporate sustainability imperatives. *Business Strategy and the Environment*, *30*(5), 2396–2420. https://doi.org/10.1002/bse.2753

Wuchty, S., Jones, B. F., & Uzzi, B. (2007). The Increasing Dominance of Teams in Production of Knowledge. *Science*, *316*(5827), 1036–1039. https://doi.org/10.1126/science.1136099