The Role of Universities in Innovation and Regional Development

The Case of Rogaland Region

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Abstract

Rogaland region, located at the southwestern coasts of Norway, has undergone tremendous economic development during the last half a century due to becoming the base for petroleum industry of this most oil-rich country of Europe. The history of higher education sector in the region has been very much shaped and influenced by that economic development history. In this article, we try to examine to what extent and in what form the main university of the region, University of Stavanger (UiS), has contributed to the economic developments in the region by corresponding to the educational, research and innovation needs of its main economic sectors. After describing the highlights of the economic and academic developments in the region, we use established frameworks from the regional innovation systems and university-industry relations literature in order to analyze whether and how the UiS has played a role in addressing the regional innovation system requirements of the sectors deemed currently as priority sectors for Rogaland. Based on that, we draw policy implications for better harmony between regional innovation system policies and higher education policies.

Keywords: Role of universities, Regional development, Innovation, Rogaland, University of Stavanger.

JEL: I23; O20; O30; R10; R58

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1. Introduction

Rogaland, hosting the city of Stavanger - known as the 'oil capital of Norway'- is an interesting case to examine in terms of universities' effect on innovation and regional development. Located in Western Norway, Rogaland has been dominantly a rural community until the end of 1960s, when the offshore oil reserves were discovered. Since then, the regional economy in Rogaland has expanded rapidly and the region has managed to become one of the most important centres for Norwegian economy.

The University of Stavanger (UiS), whose emergence also dates back to the end of 1960s, plays a complementary role in regional development and innovation system of Rogaland through its impacts on teaching, research and 'third mission' activities. Despite being oriented towards meeting the need for qualified human resources and conducting research activities for the oil and gas sector in its inception, UiS has managed to transform into a multidisciplinary character in time.

This transition is also reflected in the regional engagement endeavours of UiS, which is further strengthened by closely cooperating with public and private sector institutions in various manners, such as joint projects and common interfaces for R&D, innovation and commercialization. Although UiS has become more engaged in regional economic and social issues indisputably, the level of regional engagement seems to differ with regard to different faculties and departments, and the oil and gas sector related fields continues to dominate the regional engagement of the university. Moreover, the roles of UiS in the regional innovation systems of prevalent industrial sectors of Rogaland have also witnessed several shifts in corresponding the deficiencies.

The following paper, therefore, will try to examine the role of UiS in innovation and regional development of Rogaland region from the perspectives briefly mentioned above. The organization of the paper is as follows. The next section portrays the economic structure of Rogaland by mainly examining statistical data. Then, different theoretical approaches dealing with the issue of the role of universities in regional development and innovation will be examined briefly in order to provide the background for the upcoming discussion. Section 4 explains the formation and structure of UiS with a focus on its education and research activities. The following section examines the trajectory of the regional engagement of UiS by taking into account the industrial formation of Rogaland and theoretical background laid down earlier. The paper continues with the discussion and conclusions about the role of UiS in innovation and regional development of Rogaland. Policy recommendations drawn from the studied case conclude the paper.

2. Regional Economic Structure of Rogaland

2.1. Regional Economic History of Rogaland

It can be argued that it was fisheries and its related industries that have dominated the regional economy of Rogaland until 1970s. In mid-1800s, herring fisheries and their trade was the source of wealth in the region (Fitjar, 2010). When the region started to industrialize in early 1900s, it was the canning industry, specifically canned fisheries products, and the shipbuilding industry, related to the shipping of those products, which dominated Rogaland’s economy (Oftedal and Iakovleva, 2015). However, the discovery of petroleum in the North Sea in late 1960s was a game-changing development in the sense that a totally new industry marked the start of economic transformation for Rogaland region. Since then, regional economy of Rogaland has mainly expanded around oil and gas industry. Now, the region hosts a full-fledged supply chain in oil and gas industry, with all kinds of companies operating in the sector (Kyllingstad and Hauge, 2016).

The start of the transformation dates back to late 1962, when the American oil company Phillips asked permission to explore Norwegian continental shelf with the possibility of finding oil reserves. During the following years, the foundations of Norwegian oil and gas sector were institutionalized by the politicians in Oslo. However, it was Stavanger, the capital city of Rogaland region, which attracted the attention of international oil and gas companies to locate their operations mainly because of the geographical proximity to the planned exploration sites in the North Sea (Nerheim, 2014). However, it was not until the autumn of 1969, when Ekofisk oil field was discovered, that the prospects for economic transformation in the region could be realized. Within a couple of years, the endeavours of international firms were intensified and the institutionalization of the sector continued. The establishment of Norwegian Petroleum Directorate and Statoil, a 100-percent state-owned oil company, in 1972 in Stavanger strengthened further the position of the city as the hub of oil and gas sector in Norway. From then on, the fate of the regional economy in Rogaland is shaped by the developments in the international oil and gas sector, rather than the regional dynamics (Nerheim, 2014). Therefore, in the following, the evolution of the regional economy of Rogaland will be examined with an eye on the international oil and gas sector developments that took place globally through their effects in the overall Norwegian economy.

2.2. Effects of International Oil Sector Developments in Rogaland's Economic Structure

The existing economic structure of Rogaland and the competences in terms of shipbuilding and construction created an easy foot for the oil and gas sector to be grounded in the region (Ryggvik, 2015). However, in the early years, the large multinational corporations operating in the North Sea were conducting the engineering and planning works in their original headquarters or offices outside Norway. Even for the actual implementation phase, they relied on expatriates rather than the Norwegian workforce.

Until mid-1980s, oil and gas industry in Norway grew exponentially. The share of the sector in GDP increased from the scratch in 1971 to 17% in 1984. At the same year, the sector constituted ¼ of investments, 2/5 of exports and 1/5 of state revenues in the country (see Figure 1 in the appendix). However, the plummeting of oil prices in 1986 hit harshly the Norwegian economy with its effects to reach Rogaland in 1988. The registered unemployment rose by 67.5% in 1988 as compared to the previous year and by 74.5% in 1989 (Statistics Norway). The number of establishments also declined by 12.5% between 1987 and 1989. The economic turbulence lasted until 1993 and regional economy started to recover from then on.

International financial crisis emerged in Asian countries in 1998 also adversely affected the regional economy of Rogaland. Oil investments declined for the next 4 years and consequently, the unemployment rate in Rogaland exceeded the national average in November 1999 and remained higher until June 2002. The year 2003 marked the return of high growth times for Rogaland region that would have lasted until 2008, when another financial crisis began. The number of registered unemployed persons declined by 70% during this period (from 7,926 in 2003 to

2,362 in 2008). However, the next year, 2009, witnessed a sharp increase in registered unemployment with a rate of 93.5%.

Recently, the oil price crisis of 2014 negatively influenced Rogaland, whose effects are still being felt in the regional economy despite symptoms of revival. While the share of oil and gas sector in Norwegian GDP fell by 20% for two consecutive years (it came down to 11.8% in 2016 from 18.4% in 2014) (See Figure 1 in the Appendix), the regional unemployment rate in Rogaland doubled and reached 4.5% in 2016.

The ongoing economic problems have led to calls for a more diversified national economy, which entails repercussions for Rogaland's economic structure as being the gravity centre of Norwegian economy, which is highly dependent on oil and gas sector.

2.3. Sectoral Composition of Regional Economy in Rogaland

When the composition of Rogaland economy is examined through employment figures and value added volumes for two periods 1997-2007 and 2008-2015 acquired from Statistics Norway, a number of significant changes can be discerned (see Tables 5 and 6 in the Appendix).

The first point is related to the skyrocketing share of "oil and gas extraction including services". In terms of employment, its share almost doubled (from 5.04% to 9.73%), while its share in regional value added increased by 60% (from 11.44% to 18.36%) when compared to 1997-2007. Another sector that continued to expand during these two periods is construction. It came to account for 7.41% of regional employment and 7.34% of regional value added on average for the period 2008-2015. Health and social work constitutes the third sector where the increasing shares are witnessed, but not as high as the previous ones. Its employment share rose to 17.16%, while its value added share to 9.71%.

The second striking point is the decreasing share of manufacturing sector from 16.80% to 11.55% in employment and from 17.00% to 10.39% in value added. The biggest decline in manufacturing is seen in "the building of ships, oil platforms and moduls and other transport equipment". Its share in employment reduced from 5.55% to 2.48%. A similar decline is also seen in terms of value added of the sector (by 3.35 points). Agriculture and forestry also faced diminishing shares both in terms of employment (from 4.19% to 2.41%) and value added (from 1.46% to 0.92%) when two periods are compared.

3. Literature Review and Theoretical Perspective

The growing recognition of universities as important agents in regional development has gained prominence in the scholarly literature and policy documents in recent years. Numerous accounts in the literature point to an increasing role of universities in regional development (e.g. Charles, 2003; Guerrero, Urbano & Fayolle, 2016; Pinheiro, Benneworth & Jones, 2012). Moving from a narrow mission of the advancement of science and producing knowledgeable and enlightened citizens, universities are adopting broad missions that reflect the socio-economic needs of their regions (Chatterton & Goddard, 2000; Harloe & Perry, 2004). According to Goddard and Chatterton (1999), an array of factors in the higher education policy space and the wider economy is driving universities to adopt a more active role in regional affairs. These include the shift from the provision of elite liberal education to mass higher education, changing patterns of skills demands in the labour market owing to lifelong learning needs, declining public financial support, the regionalization of the economy through increased production and flow of global capital to the regional level and the attendant decentralization of economic regulatory institutions.

In the regional development discourses, scholars distinguish three broad roles that universities play. These are knowledge production role, entrepreneurial role, and developmental role (Charles, 2006; Gunasekara, 2006; Uyarra, 2010). Universities have traditionally functioned as knowledge producers through their teaching and research (Youtie & Shapira, 2008). Because teaching and learning, to a large extent, takes place in a localized setting, universities' teaching and research tend also to be localized or regionalized (Chatterton & Goddard, 2000). Their contribution to economic development emanates from the spillover of new research outputs and skilled human capital into the local economy, which in turn enhances the innovative capacity and competiveness of local firms or clusters (Feldman, 2003; Goddard and Vallance, 2011). This assumption rests on the premise that universities co-location with other economic actors has the tendency of engendering the economic revival or growth of regions. Such proposition, Goddard and Vallance (2011, p.428) observe, is fuelled by the few exemplar cases of Silicon Valley and Route 108, which makes the generalization of the knowledge spillover argument a bit questionable. The scholars emphasize that universities' research and development, undoubtedly, played a vital role in the formation of the Silicon Valley industrial cluster. The subsequent growth, however, emerged from the "self-sustaining innovative capacity" of the region's industrial base. Echoing this observation, Trippl, Sinozic and Lawton Smith (2015) aver that universities' role in regional development may vary depending on the structure of a region's systems of innovation, the existing knowledge bases and the dominant growth path.

In relation to their knowledge production role, universities are increasingly taking entrepreneurial or economic development roles (Clark, 1998; Etzkowitz & Leydesdorff, 2000). The knowledge generated in the universities, which hitherto was public good, has now become a 'commodity' with an economic value. Commercialization of university research in the form of licensing, patents and spin-offs is now a core mission of most universities. This development follows the enactment of laws (e.g. the Bayh-Dole Act 1980) in the US and Europe that gave universities the latitude to exploit the intellectual property rights (IPR) of their research (Grimaldi, Kenny, Siegel & Wright, 2011). The commercial activities of universities are seen to contribute to the economic growth of regions through the creation of new firms, the renewal of existing firms, the evolution of clusters, job creation and the attraction of new talent and capital (Power & Malmberg, 2008; Trippl *et al.*, 2015).

However, doubts have been raised about the potential of universities' entrepreneurial activities to catalyse regional growth (e.g. Philpott, Dooley, O'Reilly & Lupton, 2011). Some have argued that universities that do not have a strong basic or applied science research base may not be able to make a meaningful economic impact on their regions. Even among those with strong research base, few are able to profit from their IPRs with majority failing to reap significant returns from their technology transfer activities (Abreu, Demirel, Grinevich & Karataş-Özkan, 2016; Huggins, Johnston & Steffenson, 2008). Moreover, firms in a region with low absorptive capacity, low R&D intensity and weak financial base lack the wherewithal to utilize universities' IPRs and convert them into profitable products and services.

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The weaknesses inherent in the narrow entrepreneurial roles have raised calls for universities to consider broader developmental roles with economic as well as social impacts (Abreu & Grinevich, 2013; Arbo & Benneworth, 2007). Under this developmental approach, universities adapt their teaching and research to meet the industrial as well as the societal needs of their localities. Universities' staff, faculty and students adopt a proactive stance by setting the agenda for community development and working with other stakeholders or network of actors to solve community challenges (Chatterton & Goddard, 2000; Gunasekara, 2006). The extent to which universities developmental roles affect regional development is contingent on the interaction of factors such as the age and type of university, the regionalization of the higher education system, the nature of the region, regional identity and networks (Benneworth, 2013; Boucher, Conray & Van Der Meer, 2003; Trippl *et al.*, 2015).

Although this developmental role has gained currency among policy makers, the utility of this approach in helping solve regional development challenges has been questioned (Uyarra, 2010). While universities are located in regions, they are also part of a bigger scientific community from which they draw resources (Benneworth & Hospers, 2007). Therefore, adopting an overly regional focus in teaching and research in other to meet the region's developmental needs might be detrimental to the long run success and relevance of universities (Uyarra, 2010).

Taken together, there seems to be a blur in the boundaries between these roles. Universities perform combination of these functions in their engagement with regions or localities (Uyarra, 2010). This suggests that universities' contribution to regional development can be analysed through different conceptual approaches (Goldstein, 2010). We turn now to review briefly some of the conceptual frameworks that have been developed in the literature.

3.1. Conceptual Frameworks for Analysing Universities' Regional Development Roles

In the past couple of years, scholars in economic geography, regional science, and innovation studies have been working to enhance our understanding of the mechanisms that drive innovation and economic growth at different geographical spaces. Influential works that form the theoretical foundation of the field are the national systems of innovation approach (Freeman, 1995; Lundvall, 2010); regional innovation system (Cooke, 2001; Asheim & Gertler, 2005); the 'mode 2' model (Gibbons, Limoges, Nowotny, Schwartzman, Scott & Trow, 1994); and the triple helix model (Etzkowitz & Leydesdorff, 2000). These seminal works, largely, emphasized the importance of universities' agency in fostering learning, innovation and economic development. However, using these models separately do not adequately capture the evolving roles of universities in regional development. Therefore, several other researchers have proposed other frameworks, based on the synthesis of the seminal models, for a comprehensive understanding of universities' roles. Notable conceptual approaches that are identified in the literature include Gunasekara's (2006) generative-developmental model, Trippl *et al.*'s (2015) model, and Lester's (2005) industrial transformation typology. Table 1 summarizes the key premise, strengths and weaknesses of these frameworks. In the following section, we discuss these frameworks.

3.1.1. Gunasekara's generative-developmental model

Gunasekara's model builds on the regional innovation systems approach. It explicates the nature of the roles that universities perform in innovation systems development of regions and the factors that account for the variation in different regional contexts. Drawing on the triple helix and the university engagement literature, Gunasekara distinguishes two main roles that universities play in the development of regional innovation systems. These are the *generative role* and the *developmental role*. The generative role entails driving economic development through entrepreneurial activities and knowledge capitalization mechanisms such as spin-offs, incubators, science parks, knowledge transfer to firms and firm governance. The developmental role, in contrast, involves adapting universities teaching and research strategies to suit a region's knowledge and development needs.

The framework further delineates two groups of factors that explains the variations in universities' roles in different regions. These comprise *university-related factors* (university's regional engagement orientation, history of university-region linkages, and complementarity of fields) and *region-related factors* (characteristic of regional industry base, and political and economic conditions). The usefulness of this framework in analysing universities' regional development roles is the distinction it makes in different roles universities perform and the factors that explain the variations in these roles in different regional settings. This helps to correct the erroneous impression of universities as jacks-of-all-trades institutions that are capable of meeting every regional development needs.

3.1.2. Trippl, Sinozic and Lawton Smith's economic-societal development framework

Drawing on four university models in the literature, Trippl *et al.* propose an eclectic framework for analysing the economic and societal impact of universities and the policy institutions that support their engagement in different geographic settings. The framework encompasses the broader role of universities, the activities they undertake in performing these roles and the policy implications of each activity. The entrepreneurial university model and the RIS model are grouped under the *economic or technological dimension*. Typical activities universities perform under this role are commercialization of research through patents, spin-offs, consultancy, contract and collaborative research. The mode 2 university and the engaged university models, on the other hand, fall under the *social, cultural and societal dimension*. Under this dimension, universities' broader role entails activities aimed at solving societal challenges with varied actors and active political, civic and community engagements.

The Trippl *et al.*'s model, to a certain extent, is similar to Gunasekara's model. The broad classification of the university models under economic/technological, and social, cultural and societal dimensions and the related activities universities perform under the different dimension is akin to the generative and developmental roles delineated by Gunasekara. In addition, the framework also emphasizes the context-specificity of universities role in regional development. However, the point of departure of Trippl *et al.*'s framework is the synthesis of policy initiatives that influence universities to perform specific roles under differing contexts.

Table 1. Summary of the Three Analytical Frameworks

Model	**Generative-developmental**	**Economic-societal development**	**Industrial transformation**
Main proponent(s)	Gunasekara	Trippl, Sinozic and Lawton Smith	Lester
Key Premise	Universities perform generative and developmental roles in catalysing their regional innovation systems. The performance of a particular role is contingent on variations in universities internal environment and regional settings	The economic and societal development roles that universities in their regions is influenced by the prevailing national policy initiatives and incentives	Local economies develop when local industries adapt and apply new technologies to develop innovative products and services. This process industrial renewal takes place over time. Thus, universities role in regional development depends on the type of industrial transformation occurring.
Strengths	Shifting from the focus on university technology transfer role to address its broader societal roles	Comprehensive model that analyses the utility of different standalone models under varied policy regimes; brings to the fore the importance of policy institutions in shaping the behaviour of universities. This has hitherto been missing from the analysis of universities role in regional development	Dynamic model that focuses on industrial transformation process; asserts local industries' locus in regional economic growth; emphasizes universities supporting role; and recognizes importance of external actors.
Weaknesses	Static model; tends to place universities at the forefront of regional development	Static model; does not explain dynamic changes in regions	Typology tend to be idealized and simplistic; too narrow definition of economic success or growth

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3.1.3. Lester's industrial transformation typology

While the previous models discuss the roles universities are expected to play catalyse local or regional development, Lester's approach looks at universities' role in periods of local industrial transitions. According to Lester, local economies develop when local firms are able to adapt and apply new technologies in their production processes to generate new products or services continuously over time. In as much as universities perform diverse roles in regional economies, their role in local innovation processes hinges on the kind of industrial transformation occurring in the local economy.

The typology was developed based on the analysis of changes that took place in different industries in twenty-one (21) regions across six countries. From the analysis, Lester identifies four main industrial transformation processes and the possible roles universities perform during each process. These are *indigenous creation*, *transplantation from elsewhere*, *diversification technologically related industries*, and *upgrading of existing industries*. The summary of the typology is presented in Table 2 below.

Indigenous creation involves the establishment of an entirely new industry without any link to existing technology in the region's economy. In other words, it is the emergence of an ultra-new science-based industry without any linkage to existing local technological asset. Under this transition, typical university activities involve the facilitation of new business formation through incubator programs, the development of favourable licensing regimes and matchmaking between academic scientists and local entrepreneurs. In addition, influential individuals may play the role of champions or ambassadors in 'pitching' or 'selling' prospects of the nascent industry to stakeholders to help build its legitimacy.

An industrial transplantation occurs when an existing industry is imported from another region into a new locality. In this context, the industry may be old in its place of origin, however, to the destination region, it constitutes a new development. In this transition, key university functions entails development of new study programs, upgrading of existing curricula and flexible learning programs to meet the human capital needs of the new industry. Again, universities can help develop the capacity of local firms by organizing training programs for their staff and providing technical assistance to them.

The diversification into technologically related industries refers to the conversion of a declining industry's technologies to form a relatedly new industry. Put differently, it is the harnessing of a declining or collapsed industry's technological assets to develop a similar but new industry in its place. Universities' key roles in this process are twofold. First, as knowledge integrators by connecting previously separate local actors or technological activity. Second, as identity builders or legitimacy promoters of the new industry locally.

The fourth type, upgrading of existing industries, denotes enhancement of an industry's technological base through improvements in production technologies or the introduction of new products or services. These innovative add-ons give an existing or matured industry a face-lift in other to sustain its competitiveness. Local universities support this transition by increasing problem-solving interactions with industry. Another role is by providing relevant programs and continuous education and helping industry leaders search and adopt global best practices.

Table 2. Summary of Lester's (2005) Typology

Type	Description	Example	Universities Role
New industry creation	Local formation of new industry with no technological antecedent in the region	Development of PC industry in Silicon Valley. Development of the wireless industry in the region of Helsinki	Cutting edge science and technology research Prioritise technology licensing, technology transfer and entrepreneurial policies Brokering ties between academic scientists and local entrepreneurs Building an industry identity
Industry transplantation	Importation of an existing industry from elsewhere to develop a new industry in a region	The development of the oil and gas industry in Stavanger and Aberdeen following the first oil find in the North Sea	Provision of quality education Training of high calibre human capital Continuous improvement and alignment curricula to industry needs Provision of technical support and capacity building for local businesses

Industry diversification	The harnessing of a declining industry's core technologies to develop a related new industry	The development of a polymer industry in Akron, Ohio following the collapse of the region's tire industry	Building linkages between separate regional actors or technological bases Creation of industry identity and legitimacy
Industry Upgrading	The enhancement of an existing industry's technological base through improvements in production technologies or the introduction of innovative products or services	The upgrading of the pharmaceutical and food industries in Turku through the introduction of biotechnology	Problem-solving interaction with industry Exploring global best practices Provision of quality education Training of high calibre human capital Continuous

The strength of Lester's typology lies in its variation from existing models. It differs from the other models in a number of ways. Firstly, it departs from the standard models that put the onus of regional development on local universities' technology transfer and entrepreneurial activities. Instead, it reaffirms the locus of local industries as the 'engine of economic growth' with universities serving as sources of knowledge and performing other supporting roles. Secondly, it is based on a dynamic perspective that traces changes in local industrial structure and the adoption of new technologies over time. Thirdly, it acknowledges the importance of external actors' influence on local industrial development rather than viewing regional development as a function of closed interactions between local universities and industries.

Notwithstanding these strengths, the typology is not without some drawbacks. The classification of industrial transformation into four distinct classes tends to be simplistic. The assumption that industrial transformation strictly follows one of the pathways is not always the case. In reality, these transformations tend to overlap and different types of transitions may occur simultaneously in a particular region. Furthermore, its narrow definition of economic growth or success as local industries' ability to adapt and apply new technologies or innovative products and processes is problematic. This is because different factors combine to determine economic growth or development. So by exclusively focusing on the successful adoption of technology by local industry as a measure of economic growth tends to weaken the explanatory power of the framework.

4. The Founding, Educational and Research Impact of University of Stavanger

4.1. Brief History

The University of Stavanger (UiS) has experienced a period of accelerated development in the last few years. However, this recent development did not just happen by chance but series of actions rooted in the support given by regional elites and industry saw the birth and growth of this young university (Fitjar, 2006). The idea of establishing a regional university was mooted by local politicians and industrialists in the early 1960s. Following the decline in the region's key industrial activities of shipbuilding and canning, regional leaders and captains of industry reasoned that research by academics could help identify new economic drivers to stimulate economic development. However, they could not get the support of the central government because a new university had then been established in Tromsø. In the early 1970s, the need to establish a permanent higher educational institution in Stavanger became pertinent following the discovery of oil in commercial quantities in the North Sea Basin. In other to train skilled workforce for the oil exploration, a regional college and a technical college merged to start a three-year oil technology education (Oftedal and Iakovleva, 2015; Westnes, Hatakenaka, Gjelsvik and Lester, 2009).

In 1989, the vision of establishing a university in Stavanger received a major boost when parliament adopted the Hernes Committee's recommendation of reducing the number of state colleges through mergers. Consequently, in 1994 six public colleges and one private college joined to form the University College of Stavanger (HiS). The university college had to wait for another 10 years to receive a charter as a full-fledged, autonomous public university. The king of Norway, his Majesty King Harald, officially commissioned the new university in 2005. Figure 2 in Appendix traces the chronological events leading up to the establishment of UiS.

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4.2. Education Impact

From its inception, the university saw its role as providing education that meets the human resource needs of the local industry. The growth of the oil and gas industry greatly influenced the development of its educational programs. At the early stage of its founding, UiS focused on providing engineering and technology education with special emphasis on oil technology and petroleum engineering programs (Westnes *et al.*, 2009). Although UiS created a niche for itself as technical higher educational institution, over the years, it has diversified its study programs. Consistent with the growing trends in Norway towards the design of interdisciplinary study programs (Vabø and Aamodt, 2008), it now provides career-oriented courses and professional qualifications in technology, education, health and social care, economics and management, hospitality, art, culture and media. Recent reorganization of the university academic structure mirrors this change in strategy. For instance, three new faculties have been created in addition to the existing ones. Currently, the university has six faculties. These are the Social Sciences, Arts and Education, Science and Technology, Health Sciences, Business School and Performing Arts. Eleven (11) departments fall under these faculties including the Archaeology Museum. Furthermore, 63 bachelors and masters programmes are run by the university.

The expansion of faculties and the addition of new programmes indicates that the university is growing. The student population has seen a consistent increase since 2007. It grew from 7,441 in 2007 to 8,788 in 2012. In the 2016 academic year, the number stood at 10,368. Although its growth rate surpassed the national average, its enrolment was lower than similar sized national universities. For instance, University of Agder's (UiA) student population was around 7,500 but this increased to 9,497 and 11,421 in 2012 and 2016 respectively (Tilstandsrapport-hovedrapport 2017). While the university's growth has generally been sluggish, some disciplines have seen consistent growth. Two of such disciplines are the health and teacher-education subject areas. In 2012, 364 students graduated from these programs while 589 students completed in 2016 exceeding the Ministry of Education's target by 15%. By this result, UiS performed better than the established universities (University of Oslo, University of Bergen and University of Tromsø) which failed to meet their targets.

Besides the broadening of the study programs, the university also places more emphasis on digitalization in teaching and learning. Considering that technology is fast becoming an integral part of modern education, UiS has prioritized the institution of technology-rich learning environments of the study processes to help improve the quality of study. Presently, lecturers are mandated to use a blend of traditional and ICT-mediated pedagogical approaches in their teaching whereas digital skills is a key element in students' learning outcomes. In addition, communication with students and the conduct of examinations take place via digital platforms (UiS Strategy 2017-2020).

Even though leveraging digital technology in education may provide some beneficial outcomes, it is not always the case that technology-mediated practices enhance students' learning processes or the quality of education (Damşa *et al*., 2015). In the Norwegian higher education context, comparative studies that assess the impact of digital technology quality of education is rare. However, in the case of UiS, evidence from the student barometer survey suggests that the introduction of ICT-mediated teaching and learning approaches has not had the desired impact on quality of education. UiS students' perception of the quality of their studies has since 2013 been below the national average. For example, in the 2016 survey, UiS score of perceived quality was 3.87 while the national average was 4.07. In fact, the university's score was the second lowest among the all the higher institutions in the country.

Notwithstanding the perceived quality issues among students, the contrary is the case with employers. UiS's industry-focused, application-oriented and multidisciplinary educational model designed to meet the needs of the labour market is yielding some results. A study by NIFU in 2015 shows that majority of Master's graduates from the university are able to find jobs a year after graduation compared to their peers from the traditional universities. For instance, in 2013, 88% of UiS graduates secured relevant jobs while 85%, 77% and 76% of graduates from the Norwegian University for Science and Technology (NTNU), University of Bergen (UiB) and University of Oslo (UiO) respectively was employed. Even at the height of Norway's economic crisis in 2015, seventy-six percent of the university's graduates as against an average of 73% from the other three universities got employment (NIFU-rapport, 2016, p.17).

4.3. Research and Technology Transfer Impact

Research is another key area of university's function that was influenced by the oil industry. The commercial exploration of oil in 1973 brought the need for research institutions to conduct testing and other applied research for the industry. The local authorities realized that the regional college has little or no capacity in this area. They therefore established Rogaland Research (RF) as the research arm of the then regional college. RF became an independent research institute not long after its founding. In 2006, it underwent restructuring and became the International Research Institute of Stavanger (IRIS) which is jointly owned by UiS and the Rogaland Research Foundation (Westnes *et al.*, 2009).

While UiS initial research activities were shaped by the oil and gas industry, it has redirected its focus on achieving excellence in academic research. Research centres linked to the different faculties spearhead the university's research efforts. Most of the centres' projects are designed to have a multidisciplinary outlook so that there will be cross-fertilization of ideas among disparate disciplines. These research centres maintain research cooperation with local, regional, national and international research partners. The regional collaborators include the University Hospital, Business School BI Stavanger, the Norwegian School of Veterinary Science and the Diakonhjemmet College Rogaland (Oftedal & Iakovleva, 2015). The research interactions of the centres outside the region are diverse. While some are active in national research projects, others are involved in international projects. For instance, the Centre for Innovation Research (CIR) is coordinating an EU-funded research project involving six universities and seven regional development agencies across Europe.

The university has made some strides in achieving research excellence but the results cannot be described as impressive. There has been some steady growth in its publication outputs but lags behind the traditional universities on some indicators. A study by NordForst in 2017 reveals that UiS's publication volume has been increasing at an average rate of twelve percent annually from 1999 to 2014. Similarly, there was a rise in its publication points from 739.1 in 2015 to 805 in 2016 placing ninth on the top ten higher education institutions (HEIs) with the greatest increase in publication points (Tilstandsrapport-hovedrapport, 2017). Not only has the university's number of publications increased, the quality of the publications has also improved. Its publications in the top ranked journals (level 2) rose from 17.6% to 20.5% in 2014 and 2016 respectively.

On the international arena, UiS has made modest gains in its research collaborations. Its international co-publication share shot from 30% in 2010 to 46% in 2016. These gains notwithstanding, it still fell behind the 'big four' universities and Nord University. However, contrasted with citation rates, UiS performs better than its established counterparts do. Even though it has few hundreds of publications, these publications command high citation rates. According to NordForsk 2017 report, UiS had the highest percentage share (12 percent) of the top ten publications among Norwegian universities in 2011-2014. When segmented by subject fields' share of publication volume, the engineering field dominates with 32% of all UiS publications beating NTNU to second with 24%. Coincidentally, the university dedicated over a third of its research efforts to mathematics, natural science and technology (MNT) subjects in 2011-2015 (Tilstandsrapport-hovedrapport, 2017). This paints an interesting picture of UiS research orientation. Although it has made sustained efforts at broadening its research profile, its technology and engineering antecedents are still dominant.

Given that inventive ideas from research that are not commercialized remain inventions but not innovations, the university has prioritized technology transfer to industry. From its early years, UiS has maintained an active partnership with Innovation Park of Stavanger (Ipark) and Prekubator to bring their breakthrough scientific and technological ideas to the market. Ipark, which is Norway's first science park, is situated close to the university. It houses knowledge-based start-ups and other companies that provide support services to these nascent firms. One such service provider was Prekubator. It was set up in 2002 to provide technology transfer services to the then University College and other partner institutions in the region. Its function was to ensure the commercialization of researchers/scientists' and students' ideas or discoveries through patenting, licensing or spin-off ventures. To ensure the efficient provision of these services, Ipark AS and Prekubator AS merged in 2016 to form Validé. This new entity manages the intellectual property and venture portfolios of the UiS. In 2012, the university's total commercialization (i.e. business ideas, patent applications, licences and new enterprises created) was 39. This figure increased to 60 and 78 in 2015 and 2016 respectively (UiS Annual Report, 2017). It is obvious that UiS's commercialization activities are growing. However, a comparison with NTNU's commercialization efforts reveals a marked difference between the two universities. NTNU's total commercialization was four times more than UiS in 2013 and five times more in 2016 (NTNU Technology Transfer AS Annual Report, 2016).

Furthermore, UiS strives to increase research commercialization among doctoral candidates. To achieve this, the Faculty of Science and Technology in cooperation with Validé introduced a new PhD course in Innovation and Project Understanding in 2015. This program, which is compulsory for all PhD candidates in the faculty, seeks to equip candidates with the entrepreneurial toolkit to harness their research results for society's benefit.

5. Trajectory of UiS's regional engagement

In this section, we focus on the regional engagement of UiS and the way this aspect of its activities has changed over time. As our main focus in this paper is on the regional engagement through university-industry relations, and based on Lester's (2005) categorization of the university roles in regional innovation-led growth, the goal in this section is to identify the roles that UiS has played so far in the development of industries in the Rogaland region. In order to understand the development of university-industry relations in the Rogaland region, comprehending the evolution of such relationships in the broader Norwegian context can be helpful. This relationship can be specifically important at the policy level, where the national innovation system exerts huge influence over the regional innovation system (cf. Korres, 2013). This is even more so for the Rogaland region, where the (currently) most crucial industrial sector for the Norwegian national economy, i.e. oil and gas industry, is concentrated.

5.1. Layers of Norwegian Industry

Wicken (2007) has argued that the Norwegian innovation system has developed three layers of industries. These include:

- Small-scale decentralized industries (the first layer) which developed during the early 1900s.

- Large-scale centralized industries (the second layer) which became important element of Norwegian economy during the first two decades of the 20th century.
- R&D intensive network based industries (the third layer) which emerged during the last part of the 20th century.

As mentioned by Sejerstedt (1993) and Wicken (2007), the first public sector R&D in Norway were instituted at the end of 19th century to support the first layer of the Norwegian innovation system, i.e. the small-scale decentralized industries, and more specifically, the agriculture and fisheries sector. However, the establishment of technical university NTH in Trondheim in 1910 is actually considered as the start of public research support targeted at industry in Norway (Gulbrandsen and Nerdrum, 2009). This makes Norway one of the late comers with regard to public research efforts with industrial purposes in the European context. Moreover, the reorganization of NTH which strengthened its ability to support Norwegian industrialization happened only after the WWII.

Firms in the second layer, i.e. the large-scale centralized industries like metals, chemicals and pulp, have mainly appeared during the 20th century - based on the exploitation of the vast hydropower resources across the country - and have had some internal R&D capacities but have also cooperated with universities and colleges. Nevertheless, Wicken (*ibid*) explains that till the mid-20th century, the small-scale decentralized industries were still dominant in the Norwegian economy, and that political support for the large-scale centralized industries in Norway increased particularly after the WWII. He also mentions university departments as the main partner for the industrial labs of the firms in the 2nd layer.

Commercialisation-oriented research institutes in the 3rd layer, emerged during the last decades of the 20th century, and due to the vast influence and importance of the oil industry, many of them have focused their activities on serving the needs of the firms in the 2nd layer, and mainly those in the oil and gas industry (Wicken, *ibid*).

5.2. The Dawn of University-Industry Relations in Norway

Gulbrandsen and Nerdrum (2007) explain that in Norway, considerable increase in the share of industry funding of university R&D took place in the 1980s. The authors relate this increase specifically to the technological challenges of the companies active in the North Sea, and also the development of large firms within electronics and computer industry. Accordingly, they provide data indicating that in 2003 (just one year before UiS applied for getting the university status), the share of external funding for the University College of Stavanger (HiS) was 47%, which was higher than that of any Norwegian university at the time[1]. This was partly due to the oil industry's role in the Stavanger region and its need for external R&D. At the same time, in 2003, Norway removed the so-called "professors' privilege", and the higher education institutions gained the rights over intellectual property related to inventions from research carried out at the higher education institutions. Furthermore, at the turn of the century, several research policies were passed in Norway, which had implications for higher education and research organizations, giving them statutory duty to interact with external users (Thune, 2006).

5.3. UiS's Engagement Through Second and Third Mission Activities

Sæther *et al.* (2000) explain that when the system of regional colleges were instituted in the 1970s in Norway, they were primarily established as a tool for regional development, rather than for improving the national system of higher education. However, their involvement in R&D was not higher than that of the full-fledged "universities". Gulbrandsen and Nerdrum (2007) imply that the engineering college in Stavanger was an exceptional case among its peers in Norway in conducting substantial R&D. This was mainly done through the institute Rogaland Research (Rogalandforskning or RF) which was established in 1973 jointly by Rogaland Regional College (itself being established in 1969) and Rogaland County

[1] However, the fact that HiS had lower total expenditure compared to the Norwegian full-fledged universities shall be taken into account here.

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Council, and contributed largely to the newly-established oil industry in the country and the region.

All in all, the main focus of the constituting colleges of the HiS before (and also to a large extent, after) their consolidation in 1994-1995 have been limited to education, except for the department of petroleum engineering which, using RF as its applied research arm, has conducted some research activities. Notably, the Centre for Oil Recovery (COREC) was established in 2002 as a joint initiative of HiS, RF, and a number of leading Norwegian and international firms in the oil and gas industry. COREC itself contributed to the establishment of UiS in 2005, and is hosted now by the IRIS (International Research Institute of Stavanger, the former RF), and UiS is still a partner. Also, the Collaborative Competence Cluster for Industrial Asset Management (CIAM) was established in 2002 (although it has its roots in public-private partnership efforts started in the region in 1998), and ever since, the partner companies from oil industry have been its key members, as its activities have been mostly related to the offshore construction. Having created nine thematic Knowledge Hubs in the recent years as platforms for collaboration and innovation, CIAM is currently one of the most engaged research centres of the UiS.

When the oil industry in Stavanger set up a fund to transform the state college in the city (i.e. the HiS) into a university, which succeeded in achieving its goal in 2005, part of the requirement for this was to have four PhD specializations established. This was fulfilled already through having established PhD programmes in *petroleum technology* and *offshore technology* (both of which were established by 1999) and in *risk management* and *educational sciences* (both of which were established by 2003). In fact three out of the four PhD programmes established by HiS (i.e. petroleum engineering, offshore engineering, and risk management) were directly related to the activities of the oil and gas industry in the region. With gaining the full-fledged university status in 2005, three other PhD programmes were also established at the same year, in the areas of *information technology*, *chemistry and biological sciences*, and *management, economics and tourism*. Indeed, with the acquiring of university status, establishment of research centres in UiS became a priority for the UiS, but these were also initially formed mainly around the research needs of the petroleum industry in the region, and also the long established relation with the health care sector. The reorganization of RF to IRIS in

2006 is one of these efforts. The Centre for Organelle Research (CORE) was also founded in 2006, again as a joint initiative of UiS and IRIS, but also in cooperation with the Stavanger University Hospital (SUS). In fact the highest number of PhD candidates trained (or being trained) at the UiS have been so far affiliated with its PhD programmes in *petroleum technology* and *chemistry and biological sciences* (see Table 3), which further confirms the pivotal role of the relation with the aforementioned two sectors in the university's science and technology-related research activities. Nevertheless, the research centres emerging in the later years have showed "interdisciplinarity" specifics, which might be considered only as very early signs of preparation for a future transition to a Mode 2 university[2] (Gibbons *et al*., 1994), and can eventually transform the social and economic engagement model of the UiS. Notably, the Centre for Risk Management and Societal Safety (SEROS) was established by UiS and IRIS in 2009, which today consists of research groups from three departments at UiS and two departments at IRIS. One of the growing areas of the engagement for SEROS is now its participation in the Norwegian Tunnel Safety Cluster (NTSC). This is indeed in line with the growing share of construction industry in the region's economy, which has mainly taken place due to the recently intensifying tunnel construction activities in the region. In 2012, the Centre for IP-based Service Innovation (CIPSI) started its activities, which is hosted by the department of Electrical Engineering and Computer Science, but has internal collaborations with most of the other research centres at the UiS. Its goal is to strengthen the applied ICT research at UiS and IRIS, including the use of Big Data analysis in 'smart cities' (at the regional level).

In parallel with organizing the research centres and programmes, the debate around the role of UiS in *innovation* led to the establishment of Prekubator TTO in 2005, by transforming an existing Prekubator which was formed in 2002. The focus of this technology transfer office activities is on technology optimization as well as proof-of-concept stages, and does not cover the operationalization and commercialization of the ideas (Annual Report of Prekubator, 2015). The number of commercialization activities on ideas coming from UiS has so far been very low, however. Indeed, innovation activities in the departments other than the petroleum

[2] *Transdisciplinarity* is considered a characteristic of Mode 2 universities, which goes beyond interdisciplinarity, in the sense that the interaction of scientific disciplines is much more dynamic.

engineering and health sciences are not very focused yet, and are of anecdotal nature (P. Ramvi[3], personal communication, September 7, 2017). Therefore, it can be said that the interdisciplinary research activities which have emerged in the last ten years in the UiS have not systemically delivered innovation outputs yet. Furthermore, there has been efforts to upgrade the traditional sectors of agriculture and fishing into a food cluster through new initiatives like NCE[4] Culinology programme, which was established in 2007 in the Ipark, and was considered Norway's largest industrial gastronomy research group, but was closed down after the end of its funding period in 2017.

Table 3. The number of PhD candidates in UiS's PhD education specializations.

PhD programmes	Established	Candidates Dec. 2016	Doctoral defences 2008-2016
Offshore Technology	1999	19	36
Petroleum Technology	1999	48	40
Risk Management and Societal Safety – social sciences	2003	9	19
Risk Management and Societal Safety – science and technology	2003	28	36
Educational Sciences	2003	43	36
Information Technology, Mathematics and Physics	2005	31	22
Management, Economics and Tourism	2005	46	37
Chemistry and Biological Sciences	2005	34	27
Literacy	2007	22	11
Health and Medicine	2011	60	4
Sociology, Social Work, Culture and Society	2011	18	5

[3] Special Advisor at UiS on Research and Innovation

[4] NCEs: National Centres of Expertise in Norway

5.4. Role of Supra-Regional Research Networks

In understanding the relations between academic research and industry in the Rogaland region, the role of supra-regional networks needs to be taken into consideration, as these type of relations are serving an important part of the knowledge demand in the region. Strand *et al.* (2017) point out that the industrial county of Rogaland bypasses national knowledge institutions by direct contact with international knowledge institutions and customers (see also Strand and Leydesdorff, 2013). Strand *et al.* (*ibid*) point to the high rate of co-invention between Rogaland with Houston area in the U.S., indicating the strong link between the Norwegian and U.S. oil and gas industries. This has been reflected in the research and development activities of the UiS as well. In December 2015, *Norway Pumps and Pipes (NP&P)* initiative was introduced following the example of Houston. It is an interdisciplinary research and development program, which aims at using the knowledge and competencies gained in the oil and gas industry within the healthcare sector (bringing another interdisciplinary research activity to the UiS). Areas of interdisciplinary research fall within cardiology, stroke treatment technology, simulation and modelling, signal and image processing and risk modelling. The cooperative partners behind the initiative are Stavanger University Hospital (SUS), International Research Institute of Stavanger (IRIS), University of Stavanger (UiS) and Greater Stavanger. NP&P aims to reach academic and research communities across the European continent and become a European hub for the program.

Furthermore, the knowledge networks at the national level are accounting for some part of the knowledge demand in the region. Fitjar and Rodriguez-Pose (2011) point to the division of labour between Stavanger as the petroleum capital of the country and Trondheim as the main centre of research in the natural sciences in Norway. A similar supra-regional relation has been formed for research on offshore wind energy, where Christian Michelsen Research AS, located in Bergen (Hordaland region), hosted the Norwegian Centre for Offshore Wind Energy (NORCOWE) from 2009 till 2017, with UiS's CIAM as an associated partner. The annual conference *Science Meets Industry Stavanger*, which has taken place for a number of years in March or April in Stavanger, has been arranged by NORCOWE and Greater

Stavanger regional authority.[5] When it comes to the agriculture, fisheries and food industry, the research and higher education centres in other regions, such as Hordaland (UiB), Akershus (Norwegian University of Life Sciences-NMBU) and Troms (Nofima) have served the knowledge demands of the sector in Rogaland more than regional institutions.

5.5. Latest Changes in UiS Research Directions with Potential for Regional Engagement

When it comes to the engagement with industry, the science and technology departments are more prone to get involved. While the UiS's Faculty of Science and Technology had initially targeted petroleum and offshore technology together with risk management and social security (exactly the areas in which it started to provide PhD studies) as its priority areas for its 2014-2020 strategy, it has revised that strategy in 2017 (according to a presentation by the Dean of the Faculty, January 2017), based on which the Faculty's thematic focus areas will include:

- Oil and energy
- Oceanic science and technology
- Healthcare technology
- ICT and infrastructure

Indeed, while previously the thematic priority areas of the faculty have been related to the disciplinary areas, the focus is changing to prioritize cross-sectional themes, in a way that enables the faculty to deal with the societal challenges more directly (Ø. L. Bø[6], personal communication, September 21, 2017).

Furthermore, the faculty is planning to add Master's degree program in Data Science starting from 2018, together with the research area of Big Data as a new area of education and research activities. The potential for participation in the

[5] Nevertheless, the Centre's funding from the Research Council of Norway ended in March 2017.

[6] Dean of the Faculty of Science and Technology at UiS

development of Stavanger into a "smart city" can be considered as a new area of engagement for the faculty, specifically given its newly adopted focus on ICT and infrastructure. As part of this, UiS will develop a cloud data hub for gathering and analyzing big data from the EC's Triangulum project (2015-2020), in which the city of Stavanger is a partner, and will turn a district of the city into a living lab for smart city. Energy efficiency is one of the other goals pursued in the project, and in fact renewable energy (specifically offshore wind and geo-thermal energy) has proved as one of the other, more potent areas of further research and development, which would benefit largely from the existing competence in the university on offshore technology.

Overall, the university has prioritized the regional engagement in its 2017-2020 strategy document. For instance, the strategy targets to increase the share of externally funded research projects as a proportion of its total income from 20.1% (in 2016) to 25% in 2020. In fact, engagement with society is a big focus of the university now (T. G. Jacobsen[7], personal communication, May 29, 2017). Hence, it appears that UiS is consciously following a policy of furthering engagement with its regional environment. At the heart of this societal engagement strategy with the goal of societal development and innovation lies a newly created forum by the UiS, which we elaborate on in the following section.

5.6. Intensification of Triple Helix Practice in the Region

Strand *et al.* (2017) use the county-level data in Norway, and by decomposing the Triple Helix synergy into three components of *geography*, *technology*, and *organization*, conclude that the county of Rogaland has shown the highest level of regional synergy in Norway, but that this synergy is more specifically *technology-dominated*.

Inspired by the success of Linköping city-region in Sweden with the formation of a Triple Helix (and later, Quadruple Helix) organization for innovation, the Stavanger city-region has very recently formed a v*alue creation forum* (verdiskapingsforum) which was created in 2016 by the UiS board, and is led by the rector of the UiS. The

[7] Research Director of the UiS

forum is attended by representatives from private and public sectors of the region as well. The main goal is to find a consensus on the next focus areas for the region in terms of economic value creation. The forum has four *coordinated action groups*, including:

- *Innovation and commercialisation*: the purpose of this group is to strengthen the link between research, industry and entrepreneurial activities, including student entrepreneurs. The secretariat is located in Validé.
- *Big projects and cluster development*: the purpose of this group is to contribute to large-scale research and innovation projects receiving regional support. The secretariat is located at the University of Stavanger.
- *Innovation initiative*: the purpose of this group is to provide connection between innovation initiatives and conferences and arenas. The secretariat is at the Greater Stavanger authority.
- *Ullandhaug*: the purpose of this group is to become the meeting place of board directors and daily managers of the institutions located in Ullandhaug competence area. The secretariat is at the University Fund (Universitetsfondet).

The Forum is to advise the management of UiS with regard to its new regional and national engagement directions and areas. Therefore, following the latest strategy documents adopted in the university, not only a diversification in the portfolio of the priority areas for the research activities can be noticed, but also broadening of the type of the regional engagement of the university from a reactive player to a more proactive type of higher education institution is seemingly emerging. Nevertheless, the success of this very recently taken approach remains to be seen in the coming years.

6. Discussion and Conclusion

Having gone through the highlights of the economic and academic developments in the last half a century history of the Rogaland region, in this section we aim to discuss the extent to which these developments have been in correspondence, and to propose regional innovation policy for improving such a correspondence in the future.

We use Lester's (2005) university roles in order to analyse the role of UiS in innovation-led growth path of the industries in the Rogaland region. Previously, this very framework has been used in analysing the role of UiS, but mainly influenced by the dominance of the university-industry relations in the region around the petroleum industry. Comparing the roles Universities of Stavanger and Tromsø have played in the development of their respective regions in Norway, Gjelsvik and Arbo (2014, p.14) conclude that "the universities' role in local innovation processes depends on which transition pathway the region is experiencing." The authors use Lester's (*ibid*) categorization, and concerning the UiS, argue that while the initial role of the higher education sector in Stavanger illustrates a typical type 2 path (transplantation), over time, the regional oil and gas cluster in the region has matured to a type 4 path, changing the role of HiS / UiS to upgrading of existing industries. The long-term collaboration underlying this path evolution, according to the authors, is based on trust and tacit knowledge.

As indicated earlier in this paper, always a return to good years for petroleum industry in Norway (which happened in 1969, 1993, 2003) has happened one or two years before an important milestone in the history of the university (which have been in 1969, 1994, 2005). Consequently, when those milestone changes in the history of the university have been taking place, the incentive for deviating from concentration on petroleum industry-related education and research in the university has disappeared again.

However, we argue that the role of UiS in the industrial development of Rogaland region is not homogeneous across all the departments and faculties, as the RIS deficiency with which the industries in Rogaland are faced, are not all the same, and do not necessarily call for similar role from the knowledge generation institution. Lester (*ibid*, p.28) himself points to this when writing about university's contribution to local economic development: "it will likely be different in different parts of the same university to the degree that different industries are present in the region."

Accordingly, we aim to take a broader perspective in covering industries crucial for Rogaland. As mentioned in this paper, the most important economic sectors in the Rogaland region in terms of value added include:

- Oil and gas extraction including services

- Health and social work
- Manufacturing

As indicated before, the share of manufacturing industries in the regional economy has fallen compared to a decade ago, but this is not new for the region. In fact, since the establishment of petroleum industry in the region, the shipbuilding industry, which was at the core of manufacturing sector in the region, started stagnating, and this trend has continued to date. The other two important sectors, however, have kept and even increased their share in the regional economy.

Jakobsen *et al.* (2012) refer to VRI Rogaland (2007-2016), the Norwegian VRI programme's[8] Rogaland edition, implying that the composition of VRI Rogaland reflects the county's industrial structure (except the dominant, petroleum sector, which has been excluded from the programme), as it is organized in three priority areas: energy (with the aim of increasing the role of renewable energy), maritime industries[9], and food industries[10]. However, later the healthcare industry was also added as the fourth priority area, with special weight of welfare technology.

Therefore, we can opt to focus our assessment to the role UiS has played in the development of energy (petroleum and renewable), healthcare, and manufacturing (with focus on maritime and food manufacturing). In order to analyse the role of UiS in the development of these industries in the Rogaland region, firstly, we need to understand the specifics of regional innovation system related to each of these industries. So our analytical approach is based on putting the RIS deficiencies of each sector vis-à-vis Lester's categorization of university roles in regional innovation-led growth pathways.

Tödtling and Trippl (2005) distinguish between three main types of RIS failures (or RIS deficiencies), which include *organizational thinness* (referring to weak crucial

[8] VRI is an abbreviation of *Virkemidler for Regional FoU og Innovasjon*. The English title of the programme is Programme for Regional R&D and Innovation. VRI is a public innovation programme operated by the Research Council of Norway and was introduced in 2007 to stimulate research and innovation at a regional level through cooperation between research and development (R&D) institutions and industry.

[9] In the Rogaland region, special weight lies within petro-maritime industry.

[10] Rogaland has the highest employment numbers in the agriculture sector among the Norwegian regions, and follows Oslo very closely in terms of employment in the food industry.

parts in the innovation system, such as low level of clustering), *lock in* (referring to over-specialization in declining industries), and *fragmentation* (referring to lacking knowledge flows in the innovation system). We use this typology in order to assess the way UiS has confronted the demands of the regional innovation system in each priority sector of the region.

(I) Energy sector

When it comes to the energy sector, the risk of (sectoral) RIS failure in the form of R&D lock-in is high in the region[11], due to the fact that applied research in the region has been heavily dominated by prioritization of the petroleum industry. The history of UiS and IRIS's R&D activities, which have been heavily dominated by petroleum engineering, itself is a clear testimony for this risk.

Using Lester's (*ibid*) categorization of university roles in the alternative regional innovation-led growth pathways, we witness the add-up of new roles along the time vector. The UiS's role in the Rogaland region has started with the transplantation of the petroleum industry in the region through training the necessary human resource and providing the responsive curricula since its very establishment (a role which has lasted so far). Later, the upgrading of that maturing industry has been added to the first role since the establishment of IRIS and also the establishment of PhD programmes in petroleum and offshore engineering (which has also lasted so far). Recently, the diversification of this old industry into (technically) related new one(s) has been added to those previous layers, specifically with research on environmentally friendly energy and also renewable energies, the research on which is vastly benefiting from the already existing competencies in the academic and business[12] capacities in the region. The establishment of forums like the Science Meets Industry Stavanger (with focus on offshore wind energy), Nordic Edge Expo (with focus on smart cities), and also the

[11] Narula (2002) argues about the problem of systemic R&D lock-in in Norway. Further evidence comes from the industry specialization of the country; according to OECD (2011), between 1998 and 2008, Norway had the greatest increase in sectoral specialisation among OECD countries (the Hannah-Kay index for Norway decreased by 40%), making it the third most specialised OECD economy.

[12] The largest onshore wind farm in Norway (Tellenes wind farm) was inaugurated in 2017 in Rogaland.

university's recent research focus on the geothermal and offshore wind energies can be considered as the early sings of the UiS's new role in this diversification path.

Referring to Lester's four categories, Isaksen and Karlsen (2010) explain that the last two roles (i.e. diversification and upgrading) may have become more important as a result of the introduction of the open innovation model, i.e. that firms rely more on external sources of knowledge and technology in their innovation activity. Accordingly, the emerging of the era of region's economic diversification could render bigger role for the UiS as an innovation partner, as the actors involved in the diversification or upgrading of the established energy sector would open up for cooperation with knowledge generating bodies in the region.

(ii) Healthcare sector

As it concerns the healthcare sector, the current policies in the region have apparently targeted a perceived fragmentation in the sector. The plans around establishing the new university hospital at the university campus area (according to which the hospital will be ready for occupation in 2023) is a clear indication of this. Furthermore, potential plans on establishing medical doctor education in the university target the knowledge flow aspect. The UiS (and its predecessor institutions) have developed relevant educational curricula (specifically nursing education) in the higher education sector of the region, and have long been supplying the sector with the necessary human resources. In response to the fragmentation in the RIS of healthcare sector in the region, as of 2011, PhD programmes in health and social work have constituted the latest two PhD programmes established at the university. Some of the PhD research works within the biological sciences (established in 2005) have also served the healthcare sector research needs. Furthermore, CORE, SAFER (Stavanger Acute Medicine Foundation for Education and Research), Norway Pumps and Pipes, and Smart Care Cluster of Norway are some of the research and innovation initiatives which have developed by, or in collaboration with UiS. As noted, a new university hospital will be established in the Ullandhaug competence area, which would intensify the relation between UiS and healthcare sector in the region. Furthermore, IRIS has medical technology as a new priority in its research portfolio, specifically in connection with its involvement in the Norway Pumps and Pipes initiative. Therefore, using Lester's model, we can see an evolving of UiS's role in the healthcare sector from supporting the transplantation of the sector in the region in the last century through supplying the sector with human resource and responsive curricula, to the upgrading of the sector in the region through contract research and global best practice scanning and replicating. In other words, UiS's role has evolved to upgrading of the healthcare sector in the region.

(iii) Maritime sector

Concerning maritime industry, the declining shipbuilding industry in the region[13] has left the main activities of the industry in the Rogaland region around oil platform construction. While UiS's CIAM and its PhD programme on offshore technology have established some connections to the sector, supra-regional research networks seem to play a more significant role for the R&D needs of the sector. Benito *et al.*'s (2003) survey showed that the level of contact between companies in the Norwegian maritime sector and R&D institutions is generally quite low. The Global Maritime Knowledge Hub initiative was launched by the Norwegian Shipowners' Association and Maritime Industry Forum of Norway in 2008. 21 professorships and research centres were defined within the initiative to be sponsored by the Norwegian companies in the sector. Almost half of the positions were defined within NTNU, Norway's main technical university. None of the Knowledge Hub positions were allocated to the UiS. Hence, organizational thinness appears to be the RIS deficiency of the maritime sector in Rogaland, as there is no academic research and innovation capacities developed in the UiS to contribute to the functioning of the sector's RIS in the region.

[13] In fact nowadays the large shipyards are concentrated on the North-Western coast of Norway and Ålesund area, while shipping cluster is mainly formed in Bergen.

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(iv) Food production

Similar to shipbuilding industry, fish canning, which was one of the first industries established in Rogaland, experienced decline during the last three decades on the 20th century (Fløysand and Jakobsen, 1999). Also, a situation similar to Rogaland's maritime sector can be noticed for the food production sector in the region, where there is not a dedicated academic department to the R&D activities of the sector, and supra-regional research and training institutions (e.g. NMBU, UiB, NTNU, Nofima) play a more significant role in this respect. This is despite the fact that agriculture and food industry is biggest in the Rogaland region within Norwegian regions. An exception is CORE's research relations with Nofima, as well as Centre for Innovation Research's role in research on food waste and fisheries economics in Norway. However, these do not seem to fill the structural hole in the RIS of the food sector in the region. Therefore, it can be said that organizational thinness is the RIS deficiency of food industry too in Rogaland, and UiS has seemingly failed in contributing to the innovation-led growth of these industries in the region. For instance, NCE Culinology which was dubbed as Norway's largest research group within industrial gastronomy was closed down in 2017. UiS was one of the main R&D members in this only NCE of Stavanger. An evaluation report stated that NCE Culinology had still a way to go to achieve a nationally recognized gravity for the food sector (Oxford Research, 2013). The Faculty of Science and Technology's new strategy on including the oceanic science and technology in its research portfolio includes fisheries and aquaculture as a potential area of new research focus, so its implementation remains to be observed.

Table 4 summarizes our conclusion regarding the role UiS has played in corresponding to the RIS deficiencies of the priority sectors for the Rogaland region.

Table 4. Summary of UiS's role in addressing the RIS needs of priority industries in Rogaland

Priority industry	RIS deficiency	UiS role	Assessment
Energy	Lock-in	Transplantation, upgrading, and recently, diversification into related new industries.	Diversification into new related industries is a suitable response to the lock-in risk. But it is a new direction in the university's research, hence premature for assessing its success.
Healthcare	Fragmentation	Transplantation and upgrading.	Upgrading is a fitting response to the fragmentation problem. The continuously increasing relation between the university, hospital and other healthcare actors in the region indicates a successful role.
Maritime	Organizational thinness	No significant role	-
Food production	Organizational thinness	No significant role	-

7. Policy Implications

Based upon our findings from studying the role University of Stavanger has played in the innovation-led growth of priority industries in the Rogaland region, we can outline the policy implications of the paper in four points. Firstly, the fact that academic research policies and extent of their thematic concentration in regions are vastly influenced by the national higher education policies implies that there is a need for closer dialogue between regional and national innovation system actors in order to harmonize the long-term development of strategic sectors in the regions with the knowledge production capacities. The case of petroleum engineering education and research in Rogaland is a success story in this respect, even though it has not gone through a smooth path. Secondly, in order to provide the regions with a potential for securing regional resilience through adopting path renewal and path creation strategies (cf. Coenen *et al*., 2016), higher education policies shall embed a diversification vision within the curricula concentration map across the regions. The case of UiS shows us that overemphasizing the educational and research requirement of one industry may impede the sectoral RISs related to other important industries in the region from achieving their innovation aspirations. Thirdly, the transition towards Mode 2 university model, and closer engagement with the societal challenges through transdisciplinary research and innovation, requires a long-term tradition in the 'disciplinary' research areas in the first place. The fact that oil industry and healthcare sector in Rogaland have managed to replicate a global best practice interdisciplinary research collaboration (Houston Pumps and Pipes) for the region, while these two sectors in Rogaland enjoy the best and longest relationships with the higher education sector, can indicate such a conditionality. Finally, higher education policies at the university level need to have a deep understanding of regional (as well as national) innovation system deficiencies in each specific sector, and tailor their industry engagement strategies accordingly. The case of food sector in Rogaland implies that R&D collaboration by universities needs to be adapted to the realities of value chain as well as innovation cycle that is active and influential at each point in time and space, so that it delivers results in correspondence with the sectoral RIS and NIS needs.

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8. Appendix

Table 5. Sectoral Employment Averages in Rogaland

1997-2007 Average		2008-2015 Average		
Total industry	%	Total industry	%	**Change**
Agriculture, hunting and forestry	4.19	Agriculture and forestry	2.41	-1.77
Fishing and fish farming	0.41	Fishing and aquaculture	0.32	-0.08
Oil and gas extraction incl. services	**5.04**	Mining and quarrying	0.33	0.03
Oil and gas extraction	2.07	**Oil and gas extraction including services**	**9.73**	**4.70**
Service activities incidental to oil and gas	2.96	¬ Oil and gas extraction	NA	
Mining and quarrying	0.30	¬ Service activities incidental to oil and gas	NA	
Manufacturing	**16.80**	**Manufacturing**	**11.55**	**-5.25**
Food products, beverages and tobacco	2.55	¬ Food products, beverages and tobacco	2.15	-0.40
Textiles, wearing apparel, leather	0.36	¬ Textiles, wearing apparel, leather	0.17	-0.19
Wood and wood products	0.72	¬ Wood, wood products and paper products	0.58	-0.14
Pulp, paper and paper products	0.07	¬ Printing and reproduction of recorded media	0.23	-1.17
Publishing, printing, reproduction	1.40	¬ Refined petroleum, chemical and pharmaceutical products	0.08	-0.56
Refined petroleum, chemical and mineral products	0.63	¬ Rubber, plastic and mineral products	0.66	
Basic chemicals	0.11	¬ Basic metals	0.59	
Basic metals	1.20	¬ Machinery and other equipment n.e.c	3.15	-0.79
Machinery and other equipment n.e.c.	3.94	**¬ Building of ships, oil platforms and moduls and other transport equipment**	**2.48**	**-3.07**
Building of ships, oil platforms and moduls	**5.55**	¬ Furniture and other manufacturing n.e.c	0.32	0.04
Furniture and other manufacturing n.e.c.	0.28	¬ Repair and installation of machinery and equipment	1.15	
Electricity and gas supply	0.50	Electricity, gas and steam	0.35	-0.15
Water supply	0.05	Water supply, sewerage, waste	0.44	0.39
Construction	**6.28**	**Construction**	**7.41**	**1.13**

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Wholesale and retail trade, rep. of mot. veh. etc.	12.81		Wholesale and retail trade, repair of motor vehicles	12.08		-0.73
Hotels and restaurants	3.17		Transport via pipelines	0.00		0.00
Transport via pipelines	0.00		Ocean transport	2.32		-0.52
Ocean transport	2.85		Transport activities excl. ocean transport	4.46		0.13
Other transport industries	4.33		Postal and courier activities	0.55		0.00
Post and telecommunications	1.25		Accommodation and food service activities	3.14		-0.03
Financial intermediation	1.26		Information and communication	2.41		
Dwellings (households)	0.04		Financial and insurance activities	1.13		
Business services	9.39		Real estate activities	0.70		
Public administration and defence	4.78		Imputed rents of owner-occupied dwellings	NA		
Education	6.97		Professional, scientific and technical activities	4.72		
Health and social work	**16.14**		Administrative and support service activities	5.14		
Other social and personal services	3.45		Public administration and defence	4.55		-0,23
General government	25.01		Education	6.40		-0,57
CENTRAL GOVERNMENT	5.53		**Health and social work**	**17.16**		**1.03**
Civilian central government	4.87		Arts, entertainment and other service activities	2.65		
Defence	0.67		Mainland Norway	0.00		
LOCAL GOVERNMENT	19.48		¬ General government	23.68		
Market producers	72.71		¬¬ Central government	6.66		
Non-market producers	27.30		¬¬ Local government	17.03		

Source: Statistics Norway, Regional Accounts. Authors' own calculation. (Retrieved from http://www.ssb.no/en/nasjonalregnskap-og-konjunkturer/statistikker/fnr)

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Table 6. Sectoral Value Added Averages in Rogaland

1997-2007 Average			**2008-2015 Average**			
Total industry	%		Total industry	%		**Change**
Agriculture, hunting and forestry	1.46		Agriculture and forestry	0.92		-0.54
Fishing and fish farming	0.92		Fishing and aquaculture	0.57		-0.35
Oil and gas extraction incl. services	**11.44**		Mining and quarrying	0.48		-0.07
Oil and gas extraction	6.44		**Oil and gas extraction including services**	**18.36**		**6.92**
Service activities incidental to oil and gas	5.00		¬ Oil and gas extraction	NA		
Mining and quarrying	0.54		¬ Service activities incidental to oil and gas	NA		
Manufacturing	**17.00**		**Manufacturing**	**10.39**		**-6.60**
Food products, beverages and tobacco	2.25		¬ Food products, beverages and tobacco	1.70		-0.54
Textiles, wearing apparel, leather	0.25		¬ Textiles, wearing apparel, leather	0.13		-0.12
Wood and wood products	0.51		¬ Wood, wood products and paper products	0.36		-0.15
Pulp, paper and paper products	0.06		¬ Printing and reproduction of recorded media	0.18		-0.84
Publishing, printing, reproduction	1.01		¬ Refined petroleum, chemical and pharmaceutical products	0.16		-0.63
Refined petroleum, chemical and mineral products	0.78		¬ Rubber, plastic and mineral products	0.51		
Basic chemicals	0.22		¬ Basic metals	0.74		-1.46
Basic metals	2.20		¬ Machinery and other equipment n.e.c	3.07		-1.01
Machinery and other equipment n.e.c.	4.08		**¬ Building of ships, oil platforms and moduls and other transport equipment**	**2.05**		**-3.35**
Building of ships, oil platforms and moduls	**5.40**		¬ Furniture and other manufacturing n.e.c	0.28		0.05
Furniture and other manufacturing n.e.c.	0.23		¬ Repair and installation of machinery and equipment	1.23		
Electricity and gas supply	2.54		Electricity, gas and steam	1.95		-0.59
Water supply	0.17		Water supply, sewerage, waste	0.57		0.40
Construction	**5.78**		**Construction**	**7.34**		**1.56**
Wholesale and retail trade, rep. of mot. veh. etc.	8.92		Wholesale and retail trade, repair of motor vehicles	7.10		-1.82
Hotels and restaurants	1.86		Transport via pipelines	0.00		
Transport via pipelines	0.00		Ocean transport	1.84		-1.89

Ocean transport	3.73		Transport activities excl. ocean transport	4.59		0.68
Other transport industries	3.90		Postal and courier activities	0.35		
Post and telecommunications	1.39		Accommodation and food service activities	1.60		-0.26
Financial intermediation	2.60		Information and communication	3.59		
Dwellings (households)	4.94		Financial and insurance activities	2.92		0.32
Business services	11.64		Real estate activities	2.75		
Public administration and defence	4.15		Imputed rents of owner-occupied dwellings	3.81		
Education	4.91		Professional, scientific and technical activities	6.13		
Health and social work	**9.14**		Administrative and support service activities	4.42		
Other social and personal services	2.95		Public administration and defence	4.27		0.13
General government	16.78		Education	4.69		-0.23
CENTRAL GOVERNMENT	4.86		**Health and social work**	**9.71**		**0.57**
Civilian central government	4.30		Arts, entertainment and other service activities	1.65		
Defence	0.56		Mainland Norway	0.00		
LOCAL GOVERNMENT	11.92		¬ General government	16.36		
Market producers	77.80		¬¬ Central government	5.83		
Non-market producers	22.20		¬¬ Local government	10.53		

Source: Statistics Norway, Regional Accounts. Authors' own calculation. (Retrieved from http://www.ssb.no/en/nasjonalregnskap-og-konjunkturer/statistikker/fnr)

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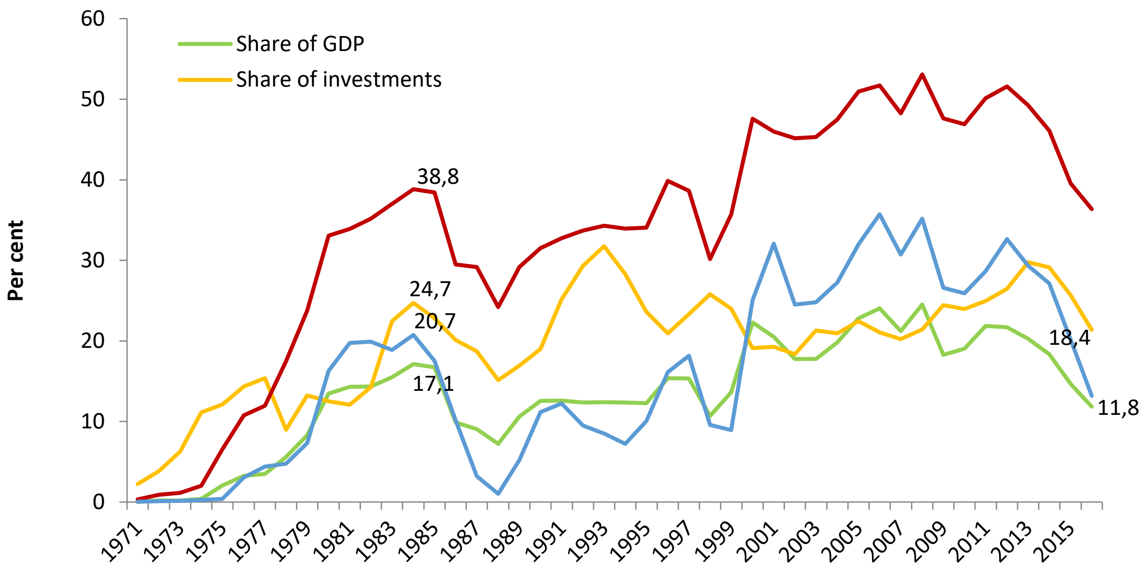
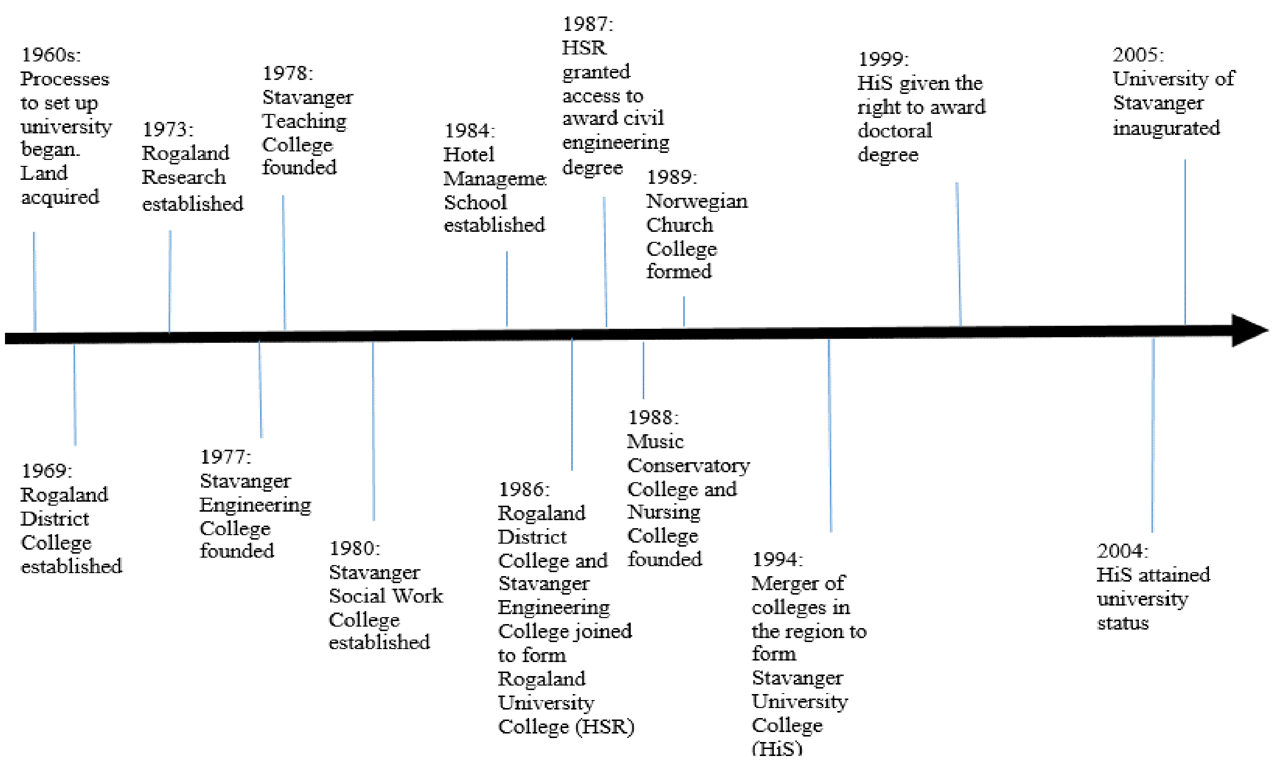
Figure 1. Macroeconomic indicators for the petroleum sector, 1971-2017



Source: Norwegian Petroleum Directorate. (Retrieved from http://www.norskpetroleum.no/en/economy/governments-revenues/)

Figure 2. The chronology of events leading to the founding of UiS



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