Knowledge Based Oil and Gas Industry

by

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Research Report 3/2011

BI Norwegian Business School
Department of Strategy and Logistics

Amir Sasson and Atle Blomgren:
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Forskningsrapport 03/2011
ISSN: 0803-2610

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Phone: 4641 0000
www.bi.no

Print: Nordberg

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Executive Summary

This study presents the Norwegian upstream oil and gas industry (defined as all oil and gas-related firms located in Norway, regardless of ownership) and evaluates the industry according to the underlying dimensions of a global knowledge hub - cluster attractiveness, education attractiveness, talent attractiveness, R&D and innovation attractiveness, ownership attractiveness, environmental attractiveness and cluster dynamics.

The Norwegian oil and gas industry was built upon established Norwegian competences in mining (geophysics), maritime operations and maritime construction (yards), with invaluable inputs from foreign operators and suppliers. At present, the industry is a complete cluster of 136,000 employees divided into several sectors: Operators (22,000), Geo & Seismics (4,000), Drill & Well (20,000), Topside (43,000), Subsea (13,000) and Operations Support (34,000). The value creation from operators and suppliers combined represents one-third of total Norwegian GDP (2008).

The Norwegian oil and gas industry has for many years been a highly *attractive cluster* in terms of technical competence. The last ten years have also seen improvements in terms of access to capital and quality of financial services provided. Value creation per employee ranges from NOK 1.2 million for suppliers to NOK 6.5 million for operators[1]. In comparison, value creation per employee in the Tourism industry is NOK 0.4 million. The supplier industry has successfully managed to internationalize, with exports from oil and gas suppliers representing approximately 15 percent of total Norwegian exports excluding direct sales of oil and gas. In addition to the export value, there is also capital income from repatriated profits from foreign subsidiaries.

Just below 50% of total mainland oil and gas employment is located in Rogaland and Hordaland, followed by Oslo/Akershus, Møre og Romsdal, the Agder counties, Sør-Trøndelag, and Buskerud. The subclusters in Oslo/Akershus (all sectors excluding Drill & Well) and in Buskerud (Subsea) have significantly higher shares of engineers/economists than other regional clusters. However, the absolute numbers of engineers/economists in the Drill & Well cluster in Rogaland and in the Topside cluster in Rogaland/Hordaland are significant.

The *attractiveness of educational* programs related to the oil and gas industry have been growing in popularity in absolute and relative terms on both the Bachelor and Master levels. However, programs dedicated to the petroleum industry have been losing students in recent years. This situation reflects the continuing interest in engineering and related topics with an increasing focus on renewable energy and other technologies that are perceived to be more environmentally friendly. For doctoral studies, both the absolute number of students and the relative proportion of students are declining. As doctoral studies have the longest time horizon, investment in such studies indicates that there are opportunities for either advanced employment or future academic life within this specific area. Taking this into consideration, the declining attractiveness of doctoral programs in the relevant areas might constitute an early signal that the opportunities for advanced R&D-based value addition in the oil and gas industry are declining.

The oil and gas industry used to have a relatively low proportion of higher educated personnel, but this gap has now been closed and the industry is just as *attractive for talent* as other Norwegian industries. Many engineers work in the oil and gas industry, although their

[1] An *estimate* of the petroleum rent has been deducted.

share is declining, while there is growth among workers with business, economics and other social science backgrounds. If this trend continues, parts of the cluster may move from exploration and the creation of new, engineering-based products/solutions towards the exploitation of already developed products/solutions or more labor-intensive work, such as maintenance and modification offshore (MMO). The industry has attracted many foreign workers in recent years. However, most were hired on the basis of the cost advantages associated with these workers rather than their specialized knowledge.

Practical challenges encountered in the oil and gas activity on the Norwegian continental shelf have given birth to a number of important innovations through a close cooperation between operators and suppliers. This has made Norway into an *attractive location for oil and gas R&D* with many international oil and gas companies, e.g., Schlumberger, locating their R&D to Norway. 31 percent of all Norwegian-based oil and gas companies use 4 percent or more of sales on R&D, and innovate more than the other Norwegian industries in terms of products, services and organizational practices. Even though these figures are based on a wider definition of the supplier industry, they indicate serious flaws in the OECD's measurement of R&D and innovation in the Norwegian oil and gas industry, and, consequently, that Norway's persistently high level of productivity and per capita income is not really 'puzzling'. However, if the future holds less activity on the NCS and fewer large field developments, the NCS might become a technological backwater. This may force the supplier industry to look to foreign oil and gas hubs for knowledge and learning.

When oil and gas activities began in Norway, the country already possessed an international maritime industry, and industrial actors within the fields of fabrication and construction. However, Norway lacked oil and gas-specific competencies. The Norwegian government therefore introduced policies to *attract global competence/ownership*. Due to the presence of the large partially state-owned operator Statoil, the share of foreign ownership in the total Norwegian oil and gas industry (37%) is much lower than the share of foreign ownership among suppliers (just above 50%). The reliance on foreign-owned companies distinguishes the elements of 'infant industry protection' in the build-up of the Norwegian oil and gas industry from other countries' experiences. Another factor working towards a high share of foreign ownership, especially in the suppler industry, seems to be that Norwegian-owned start-ups ready to introduce a product to a larger market tend to look for global industrial partners with financial strength. However, foreign takeovers of Norwegian-owned companies do not harm the development of the national cluster if, like in the case of subsea technology, the R&D is grounded in Norway so that most R&D and headquarter functions remain in Norway.

The oil and gas industry is currently perceived as not very *environmentally attractive* even though it employs a number of environmentally friendly technologies. There are also ongoing initiatives, such as the utilization of microorganisms, to produce win-win solutions. Furthermore, the Norwegian oil and gas industry's environmental standards make it an attractive oil and gas hub in which to do business. This aspect needs to be emphasized further. However, the development of higher environmental standards is called for, particularly given the plans to extract oil and gas in the northern areas. Norway must be at the forefront of the global industry in terms of developing environmentally friendly solutions.

The *cluster dynamics*, or the innovation system, in the Norwegian oil industry is based on a high degree of collaboration between suppliers of technology solutions and their customers, the operators. Intra-industry labor mobility is operator-centric as operators are the preferred

employment destination and technology-heavy-cohesive grouping as there are disproportionately large and reciprocal labor movements, especially among Geo & Seismics, Drill & Well and Subsea. Clusters thrive in the presence of related clusters, and the oil industry has woven a tight network of relations, supported by the transfer of labor to and from the maritime industry, the metal processing industry and advanced knowledge mediators. Firms in the oil industry invest in competence development as much as firms in the health industry, although the latter is considered to be a much more knowledge-intensive industry. If we combine the intra-industry labor mobility findings with the fact that the main focus of recruitment is on people with industry experience, a reduction in the activity level of the supply industry will also affect operators, as competent labor gains its experience in the supply industry before moving to operators.

Business strategy implications: Recommendations

- Prepare for decades of maintenance, modification and decommissioning, and of 'difficult' oil and gas production in an increasingly cost-sensitive environment.
- Prepare for increasing low-cost foreign competition, which will initially be evident in the labor-intensive sectors of construction and manufacturing.
- Internationalize through the establishment of foreign subsidiaries by Norwegian headquarters.
- Contribute to promotion of the industry to help increase the critical supply of engineers, both from within the country and from abroad
- Invest in R&D and collaborations with R&D institutions.
- Find ways of channeling learning from foreign oil and gas activity to Norwegian-based R&D communities.
- Establish a proactive environmental involvement to appropriately respond to some of the major risks associated with oil and gas extraction.
- Establish a new petroleum innovation system that is not dependent on the 'Big Brother' (NCS Operators), one possible development would be a collaboration between technologically advanced suppliers and systems integrators.
- Explore commercially viable opportunities based on their core competencies for markets outside the oil and gas industry. Given the high cost level in Norway, these applications will have to be highly engineering intensive.

Knowledge-based industrial public policy: Recommendations

- When considering the possibility of opening new areas to oil and gas activity, the government should bear in mind that increased activity will provide the industry with a laboratory for technology development.
- The government should set unprecedented environmental standards that not only secure the environment in northern Norway but also allow the Norwegian oil and gas cluster to remain at the forefront of environmentally friendly solutions. Investments that improve upon the conditions under which innovative environmental solutions can be developed should commence in good time before standards are set.

- To ensure a reliable supply of engineers, the government should promote science-based education at an early age and consider the Australian and Singaporean models for attracting highly educated immigrants.

- Should the size of fields on the NCS and, thus, their relative economic profitability be reduced, the government should consider a revision of the tax system to reduce disincentives for the application of knowledge.
- To assist Norwegian suppliers in adapting to an environment with reduced activity on the NCS and with more distant relations with Norwegian-based operators, the government should invest in 'knowledge infrastructure' by funding for a) petroleum-related research programs (e.g. PETROMAKS, DEMO2000); b) the 'industrial PhD program', c) investments in the NCE and Arena programs, and d) advanced test facilities in collaboration with R&D institutions and NCEs.

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1 Introduction: Clusters and global knowledge hubs

In this study, we assess the underlying properties of a global knowledge hub to examine the extent to which the Norwegian upstream oil and gas industry – defined as all oil and gas-related firms located in Norway, regardless of ownership – constitutes such a hub. We commence with a general discussion of the industry before we examine the underlying properties of global knowledge hubs: cluster attractiveness, education attractiveness, talent attractiveness, R&D and innovation attractiveness, ownership attractiveness, environmental attractiveness and cluster dynamics. We conclude by providing clear recommendations for business and public policy.

The case of the Multiphase Meter market

In traditional oil and gas production, the different 'phases' of the well stream (oil, gas and water) are separated at the well head. For subsea completed wells, separation at the well head is not possible and the rate of recovery is, therefore, considerably lower than for topside wells. In the early 1980s, this challenge led to academic research on the development of reliable multiphase meters.

In Norway, different multiphase meter technologies were developed. Christian Michelsen's Research (CMR) in Bergen developed a multiphase meter that was commercialized through the company's subsidiary Fluenta. Bergen-based Framo Engineering entered into a joint development program with Hydro and Shell with the aim of further developing the combination of technology elements offered by the various parties. This program resulted in the development of what has proven to be a high-performance multiphase meter. In Stavanger, the small entrepreneurial start-up Multi-Fluid began to develop the MFI multiphase meter technology.

When the technologies were ready for commercialization, a search began for industrial partners with financial strength. Framo Engineering entered into a 50/50 joint venture with Schlumberger. This joint venture remained a technology development and supply firm even after Schlumberger acquired majority ownership in Framo Engineering. In 1999, Multi-Fluid merged with Smedvig Technologies (a subsidiary of the Stavanger-based Smedvig Group) to become Roxar ASA, which in turn acquired Fluenta. Roxar was acquired in 2009 by the US-based firm Emerson Process Management. In 2003, several former Roxar employees established Multi Phase Meters (MPM), which was acquired by FMC Technologies in 2009. While the bulk of technological development has been financed through internal sources, all three companies have also benefited from public research grants.

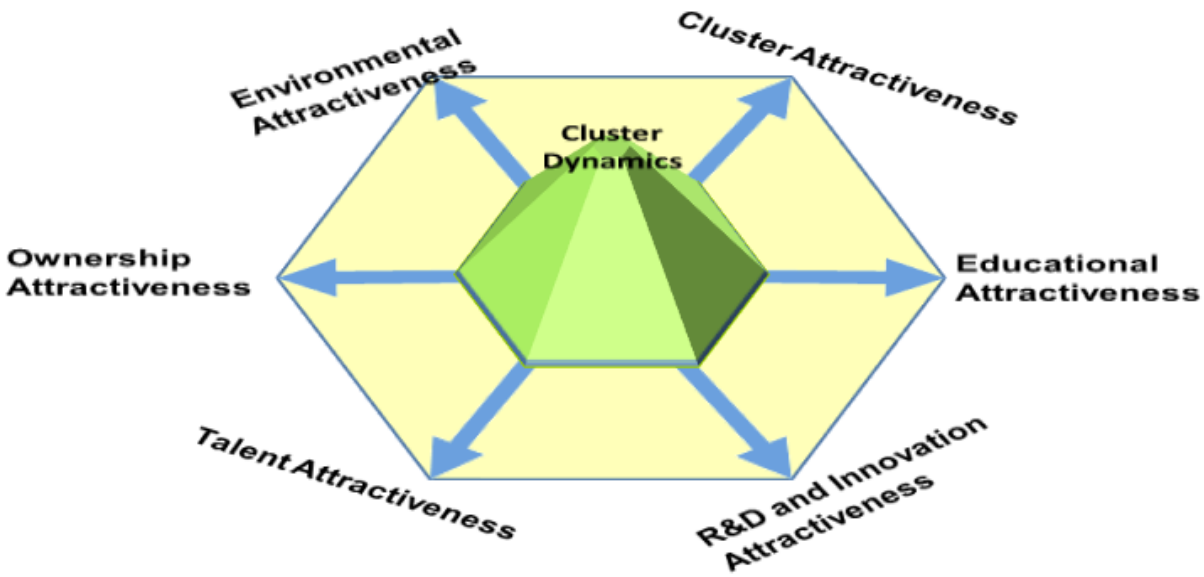
The multiphase meters of Framo Engineering, Roxar and MPM have proven very successful in operations on the Norwegian Continental Shelf, and all three firms now sell their technology in foreign markets. The global market for high-end multiphase meters, currently valued at NOK 2 to 3 billion, is shared by Roxar, Framo Engineering and MPM. Even though all three Norwegian producers of multiphase meters are controlled by global systems providers, design and development are kept in Norway.

As a microcosm of the development observed in the Norwegian oil and gas industry over the last 40 years, the multiphase meter case introduces many of the factors common to technological development in the industry. First, technological developments have been fueled by practical challenges on the Norwegian Continental Shelf (NCS). Second, technological developments have come about through a combination of original research and the adaptation of existing technologies. Third, development work has often been conducted in collaborations established among operators, suppliers, R&D institutes, capital owners, and governmental research and innovation agencies. Fourth, technologies developed for the NCS have often been exported to other oil and gas producing regions. Fifth, new companies established as a result of technological development have often turned to foreign industrial partners for financial support and market access, but in situations when technological development remained locally rooted the firms have stayed in Norway.

Global knowledge hubs

For Norway to be able to sustain its wealth in the future, an adjustment process must be initiated while oil reserves are still being exploited. Recently published innovation indexes (e.g., OECD 2010) raise concerns about the relative speed and comprehensiveness of the adjustment process in Norway. To address the shortfalls in the adjustment process, tough decisions are required on the national level. These decisions will affect Norwegian businesses and their representative organizations, educational institutions and governmental agencies.

Figure 1-1: The global knowledge hub© model



This study is based on three simple premises. For industries to be competitive and sustainable in a high-cost location like Norway, they have to compete globally, they have to be knowledge based and they must be environmentally robust. Under such conditions, nations and regions face the challenge of attracting the best talent and the best firms. Knowledge-based industrial development is argued to occur in global knowledge hubs or superclusters characterized by a high concentration of innovative industrial actors interacting closely with advanced research institutions, venture capital firms and competent owners. Hence, firms,

local authorities and national governments face the challenge of creating conditions under which knowledge based industrial development can occur.

The Global Knowledge Hub© model presented in Figure 1-1 provides a framework for analyzing the attractiveness of localities. The surface of the hexagon represents the room for maneuvering available to public authorities and a decision set for firms. It conceptualizes attractiveness as six dimensional. Localities differ in their attractiveness in accordance with their abilities to attract advanced-education institutions and departments, highly talented employees, advanced academic specialists, research and development projects, competent and willing investors and owners, the creation and implementation of environmental solutions, and a diverse and sizeable group of related firms.[2]

The effects of these dimensions on economic performance are moderated by the degree of cluster dynamics. Cluster dynamics refers to the extent to which related firms structure their internal and external relationships. The objectives are to identify existing and emerging global knowledge hubs, and to recommend policy initiatives designed to enable the further development and competitiveness of such hubs.

The next section presents an overview of the development of the industry over the past decade. We then examine the underlying attractiveness properties that affect the success and failure of industrial initiatives within the Norwegian oil and gas industry. In the concluding section, we discuss implications for firm strategy and public policy.

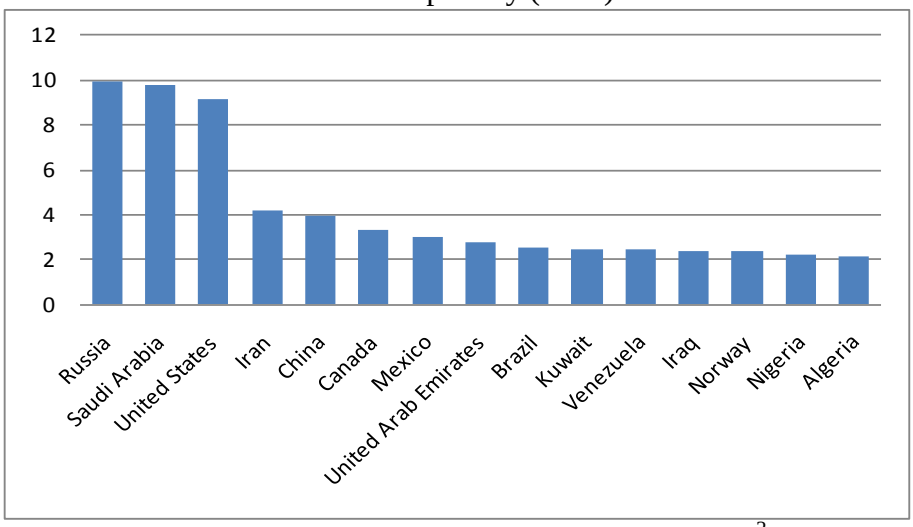
[2] In this study, we ignore the cultural dimension of attractiveness.

2 The Norwegian oil and gas industry – past, present and future

Until 50 years ago, it was believed that Norway did not possess any oil and gas resources. After the discovery of gas in Groningen in the Netherlands in 1959, global oil and gas firms directed their attention to the NCS and, in the autumn of 1962, Phillips officially asked Norwegian authorities for permission to start explorations on the NCS (Ryggvik 1997). In 1969, these explorations paid off with the discovery of the Ekofisk field, which was followed by a number of major discoveries in the years thereafter. The commencement of production at the Ekofisk field on June 15, 1971 marked the beginning of the Norwegian oil and gas era.

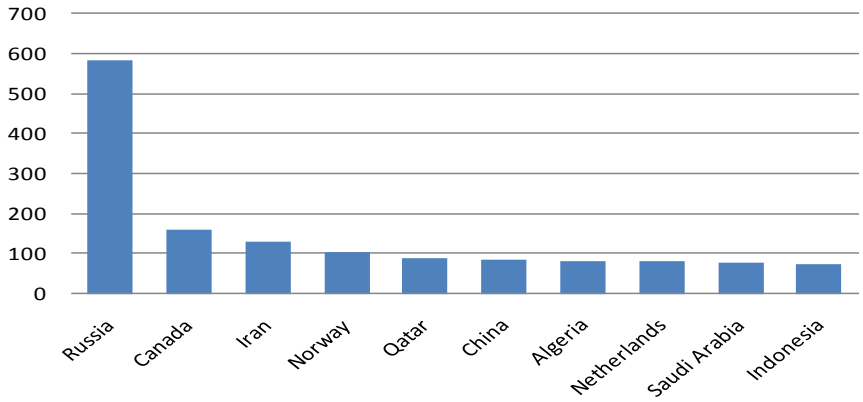
> "The initial Ekofisk development was completed in 1975. Norwegian participation was limited. [..] Engineering and procurement was mainly performed in London, and besides construction of the Ekofisk storage tank and some verification work by Det Norske Veritas, very little activity took place in Norway." (Hagen 2001)

Figure 2-1: Production of oil (including natural gas liquids (NGL) and condensates), millions of barrels per day (2009)



Source: US Energy Information Administration[3]

Figure 2-2: Production of natural gas, billion scm per year (2009)



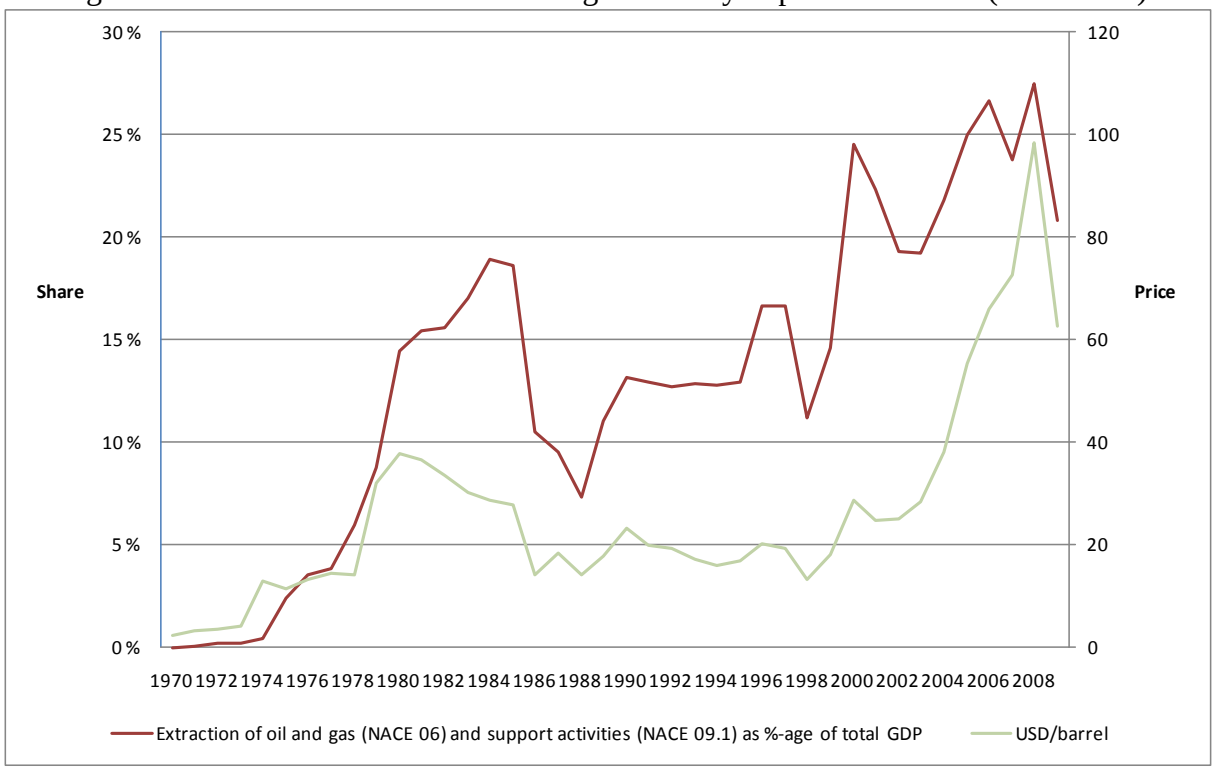
Source: US Energy Information Administration[4]

[3] http://www.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=3&pid=26&aid=1#

In 2009 the 65 producing fields on the NCS yielded 2,4 barrels of oil per day (Figure 2-1) and 103 billion scm of natural gas per year (Figure 2-2), making the world's 13th largest producer of oil and the fourth largest producer of natural gas. Total annual Norwegian production in 2009 was 238.6 million scm of oil equivalents (approximately 1.5 billion barrels).

Investments on the NCS have been substantial. The NOK 130 billion invested in the NCS in 2010 represented approximately 10 percent of total global oilfield investments (Fjose *et al.* 2010b). Non-exploration investments in the NCS have also been substantial. It current terms, investments increased by 50 percent from 2004 to 2010 and they are expected to increase further in the near future (see below).

Figure 2-3: Value creation in the oil and gas industry in percent of GDP (1970-2008)



Source: Statistics Norway

If the oil and gas industry is defined using the traditional statistical definition of the oil and gas industry NACE -codes 6 (extraction of oil and gas) and 9.1 (support activities) (see for instance Norwegian Petroleum Directorate 2010a), then – the Norwegian oil and gas industry's share of GDP industry has grown from only a tiny fraction of GDP in 1973 to 21 percent in 2009 (cf. Figure 2-3).

As is shown in section 2.1.2, the industry's increased significance is not only due to increased production but also to the development of a Norwegian-based supplier industry. As Figure 2-3 shows, the industry's share of total GDP varies with oil and gas prices. While the industry

[4] http://www.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=3&pid=26&aid=1

accounted for 19 percent of GDP in 1985, its share was only 7 percent in 1988. The industry reached its peak in 2008, when its share of GDP reached 27 percent.[5]

2.1 Licensees/operators and suppliers

In the first decades of global oil and gas exploration, the large western oil and gas firms took the titles (licenses) to resources, operated the fields and provided all necessary services. As a result of the 1973 oil crisis, oil and gas firms realized that the industry structure would not be as stable as in previous decades and that their own organizations would have to change accordingly (Jones 1988). The need for a more flexible workforce, coupled with the large oil firms' generally favorable redundancy and early retirement provisions, made it more economically sound to outsource activities to external supplier firms. Thus, the global supplier industry was born (Jones 1988). "[T]here is hardly any function, however technical or esoteric, in the oil industry, which cannot be performed by a service contractor. [...] [T]he most specialist work in the industry is in fact frequently undertaken by such firms." (Jones 1988: 206-207).

A licensee/operator requires a large number of services, ranging from the highly specific and technical (e.g., drilling and well intervention) to the more generic (e.g., catering at firm headquarters). Between these two extremes lie generic activities that need some modifications to be used in the supplier industry, such as adjusting ordinary vessels for seismic shooting. As is discussed in more detail in section 12, there is no unanimity on how to distinguish between specific and generic oil and gas suppliers. In this report, the term 'oil and gas supplier' is used both for firms that provide services specifically aimed at the oil and gas industry, and for firms that provide generic services that need 'some' modifications before being provided to the oil and gas industry.[6]

The Norwegian oil and gas industry is thus divided into:

Licensees/Operators (henceforth referred to as 'Operators'), are firms that hold production licenses or have been granted operatorships of oil or gas fields (e.g., Statoil, Shell and Skagen44). This sector consists of 179 entities with a combined employment of 22,000. The largest firm, Statoil, has more than three-quarters of the total employment in the industry. ConocoPhillips and Shell are second and third with employment of 1,800 and 1,000, respectively.

Oil and gas suppliers are those firms that provide oil and gas-specific services (drilling and well intervention, etc.) and/or generic services modified for use in the oil and gas industry (offshore supply vessels, etc.). See the further specification in subsection 2.1.2.

2.1.1 Licensees/Operators

Licenses for exploration and production on the NCS have been awarded through 20 numbered concession rounds, one Barent Sea concession round (1997), four North Sea concession

[5] It should be mentioned that while the traditional statistical definition of the industry is frequently used (see, for instance, NPD (Norwegian Petroleum Directorate 2010a), many would argue that limiting the supplier industry to companies registered under NACE code 9.1 (support activities) leads to an underestimation (Vatne 2007). This point is revisited in this section and in section 12.

[6] While this definition captures most of the supplier industry, there are admittedly some problems with defining the amount of modification that needs to be present before a firm can claim to be an oil and gas supplier. The auditing of oil and gas firms, for instance, has not been included but it could be argued that such auditing requires only 'some' modification of ordinary auditing procedures.

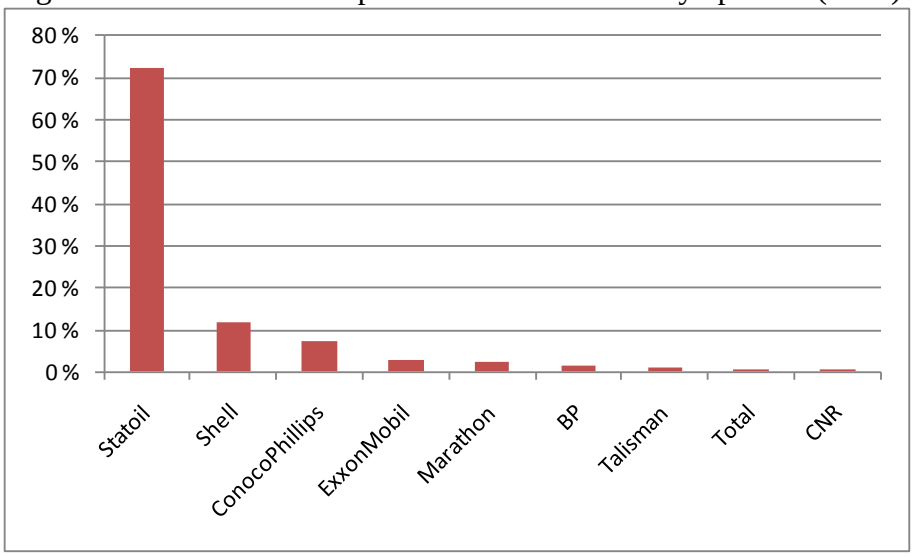
rounds (1999-2002) and, since 2003, annual Awards in Predefined Areas (APA). In the first concession round in 1965, the majority of production licenses were awarded to foreign-owned[7] firms. Of the 81 blocks available, 22 were awarded to companies or partnerships with Norwegian interests, including the partnership between the US company AMOCO and the Norwegian Oil Consortium (NOCO), and the newly established oil and gas subsidiary of the Norwegian-owned manufacturing conglomerate, Hydro. In 1972, the Norwegian Parliament established a publicly owned oil and gas firm, Statoil. Throughout the 1970s Hydro, and NOCO, which changed its name to Saga, acquired production licenses by participating in the concession rounds. Until 1985, the state-owned Statoil was granted licenses directly and did not have to participate in the concession rounds. In the fourth concession round in 1978, the three Norwegian-owned firms obtained 58 percent of the production licenses awarded. In addition, Statoil was chosen as operator for three blocks, while Hydro and Saga were selected as operators of one block each. In 1981, Statoil's first operating license (Gullfaks) came into production, and the firm became the first Norwegian-owned operator of an oil and gas field.

The importance of Norwegian-owned oil and gas firms increased during the 1980s. A 1983 parliamentary white paper stated that if the awarded licenses developed as expected, Statoil would be responsible for an estimated 70 percent of all production on the NCS by 2000, while Hydro and Saga together would be responsible for less than 10 percent (Government white paper no. 73 (1983-1984)). To avoid Statoil's dominance of the NCS and to ensure that the firm would operate on same terms as other companies, parliament decided in 1984 that the Norwegian state's engagement in oil and gas activity should be split. One part would continue to be managed through the state's ownership of Statoil with the requirement that Statoil would have to participate in the ordinary concession rounds. The other part of the state's engagement in oil and gas activity would be managed through direct ownership of stakes in oilfields via the State's Direct Financial Interest (SDFI). The SDFI was managed by Statoil until it became a public firm in 2001, at which time the management of the SDFI was transferred to the newly established state-owned firm Petoro.

In 1999, Hydro acquired Saga, and Hydro's oil and gas division merged with Statoil in December 2007. One major reason for the merger was Statoil's need to increase its size to be able to compete in foreign markets. Statoil is now responsible for over 70 percent of all oil and gas production on the NCS (Figure 2-4). In addition, it has extensive operations in other oil and gas regions around the world.

[7] When ownership is an issue, this report distinguishes between Norwegian owned (i.e., Norwegian – owned capital holds a controlling stake) and foreign owned (i.e., foreign capital holds a controlling stake).

Figure 2-4: Distribution of production on the NCS by operator (2009)

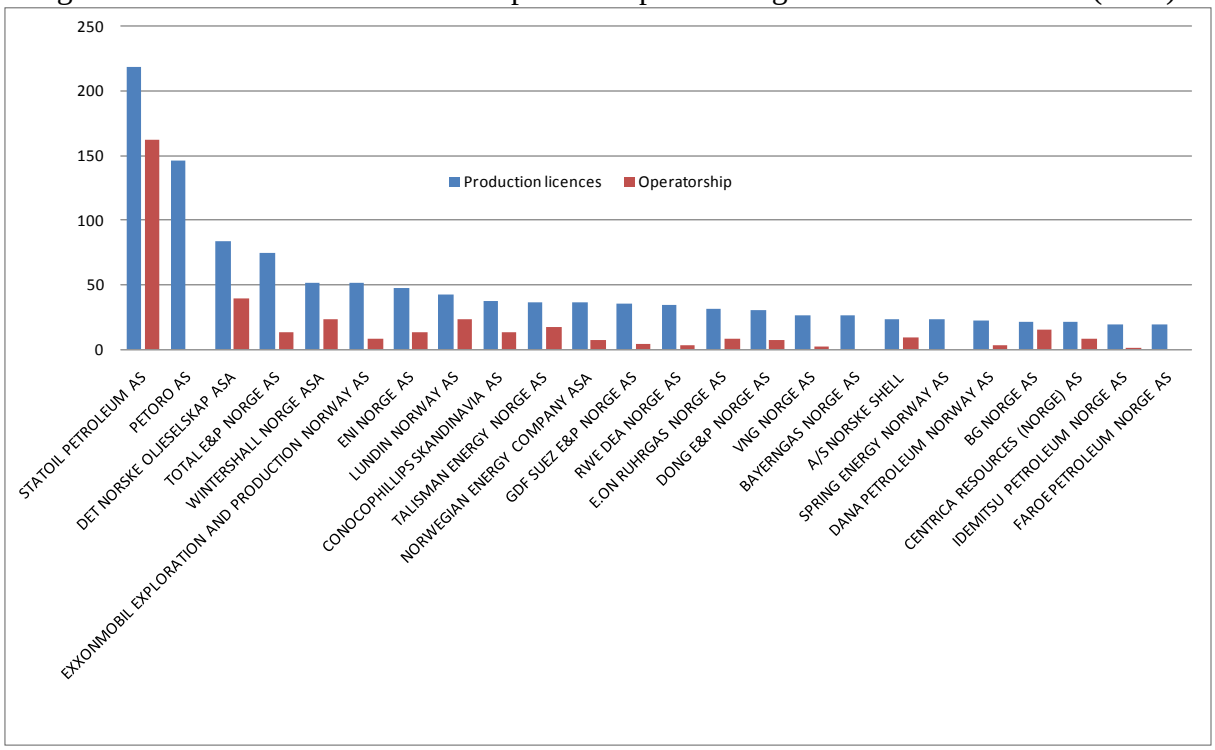


Source: Norwegian Petroleum Directorate

A main concern for the Norwegian Parliament has been ensuring that the maximum amounts of oil and gas resources are extracted. To this end, Parliamentary White Paper No. 39 (1999-2000) allowed for an increase in the number of licensees/operators on the NCS and introduced a system for prequalification of potential new licensees. However, the large capital outlays required in the early phases of oil and gas exploration remained an obstacle for smaller firms. As the marginal tax rate on income from oil and gas production on the NCS is 78 percent, firms with an income stream in reality only pay 22 percent of all exploration costs. To attract new licensees/operators and to level the playing field between companies with and without production income, the Norwegian Parliament decided in 2004 that licensees/operators without an income stream would be refunded the full tax value of their exploration costs, i.e., 78 percent of all exploration costs. As a result of these policies, a large number of new firms have been able to meet the prequalification criteria. The Norwegian Petroleum Directorate (NPD) (2010) reports that 62 firms have been prequalified or established as operators since 2000.

At present, there are 1,405 production licenses and 437 operatorships on the NCS. There are 52 licensees, of which 35 also hold operatorships and 17 hold only licenses. Statoil has the largest amount of both, with 219 licenses and 162 operatorships. Petoro is second with 146 licenses and no operatorships. Figure 2-5 shows the distribution of production licenses and operatorships among the 24 largest holders of production licenses.

Figure 2-5: Production licences and operatorship following 20th concession round (2009)



Source: Norwegian Petroleum Directorate

As Figure 2-5 indicates, the smaller firms are particularly active in exploration. In 2009, they accounted for about 50 percent of all exploration on the NCS. The emergence of many small firms holding production licenses and operatorships resulted in a dramatic change in the composition of the investing firms. In 2000, 80 percent of all exploration costs related to the NCS were incurred by large firms. By 2009, this share had been reduced to 40 percent. New firms are now responsible for more than 50 percent of exploration costs, while the remaining 10 percent is invested by medium-size firms (Norwegian Petroleum Directorate).

2.1.2 The Norwegian-based supplier industry

This study focuses on a population of approximately 2,500 petroleum-related firms (for details, see the appendix in chapter 12) involved in the Norwegian oil and gas industry. The industry employs 136,000 persons, of which 22,000 are employed by operators and 114,000 are employed by suppliers.[8] This supplier employment figure is somewhat higher than figures presented by Vatne (2007), Ernst & Young (2009) and ECON (2010), but it is in line with Eika, Prestmo and Tveter (2010b) when adjusted for employment in generic activities.

To allow for further analysis, each firm in the population is classified on two dimensions: the *activity* in which the firm is engaged and the *sector* in which the firm operates. The sector classification is carried out using multiple external sources and the authors' knowledge of the industry. The activity classification is based on NACE codes as follows:

[8] As is made clear in section 12, two sectors are left out of the population: public administration related to oil and gas (e.g., the Norwegian Petroleum Directorate), and oil and gas-related research (e.g., SINTEF, CMR, IRIS).

- Engineering-based services: firms within NACE codes 06 (operators), 09 (support activities), and 58-74 and 78-82 (provision of services),
- Manufacturing: NACE codes 22-28 (manufacturing),
- Equipment supply: NACE codes 46 (wholesale) and 77 (rental of equipment),
- Construction and maintenance: NACE codes 30-33 (construction and repair),
- Maritime operations, rigs and FPSOs: NACE 50 (sea transport) and firms manually registered as maritime operations, rigs and FPSOs, and
- Support facilities: NACE codes 38 (renovation), 49 (land transport), 52 (services connected to transport) and 56 (catering).

The sectors in the supplier industry can then be described as follows:

Geology, Seismics and Reservoir: This is the smallest sector with 149 entities and 4,000 employees (Table 2-1). Activities are divided into computer-assisted modeling of reservoir data (engineering-based services), and acquisition and processing of seismic data (maritime operations). Large firms within data processing are Schlumberger Information Technology Services, Geoservices and Landmark Graphics. Large firms within maritime operations are WesternGeco, PGS Geophysical and Electromagnetic Geoservices.

Table 2-1: Value-creation system in the Norwegian oil and gas industry, employees (2008)[9]

	Engineering-based services (NACE 06, 09, 58-74, 78-82)	**Manu-facturing (NACE 22-28)**	**Equip-ment supply (NACE 46 and 77)**	**Construction and main-tenance (NACE 30-33)**	**Maritime ops., rigs and FPSOs (NACE 50 ++)**	**Support facilities (NACE 38, 49, 52 and 56)**	**Total**
Operators	22 000						**22 000**
Geology & Seismics	2 000				2 000		**4 000**
Drill & Well	10 000	4 000	1 000		5 000		**20 000**
Topside	7 000	9 000	1 000	26 000			**43 000**
Subsea	2 000	2 000		5 000	4 000		**13 000**
Operations Support	8 000	5 000	4 000	4 000	8 000	5 000	**34 000**
Total	**51 000**	**20 000**	**6 000**	**35 000**	**19 000**	**5 000**	**136 000**

Source: Statistics Norway – Employment Register, IRIS/BI

Drill & Well: This is a medium-sized sector consisting of 235 entities with total employment of 20,000. The sector can be divided into four subcategories: 1) engineering-based firms running drill and well operations (e.g., Halliburton, BakerHughes, Seawell, etc.); 2) manufacturing of drill and well equipment (e.g., the NODE cluster in southern Norway); 3) equipment supply (M-I Swaco); and 4) administration of rigs and FPSOs (e.g., Seadrill, BW Offshore).

Field Development Topside: This is the largest sector and comprises 404 entities with 43,000 employees. Sector activities include the construction of offshore-related vessels, the construction of surface installations, and the maintenance and modification of onshore and offshore production facilities (MMO). The sector can be divided into four subcategories: 1)

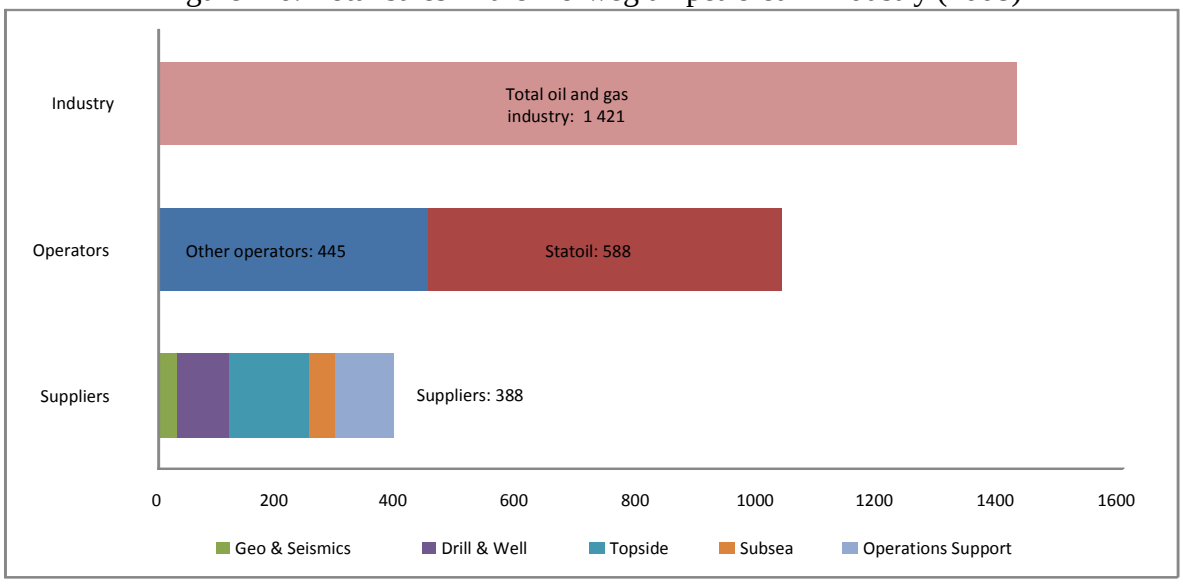
[9] Rounded to the nearest thousand.

engineering-based firms (e.g., Aker Solutions, Fabricom, Apply Sørco); 2) manufacturing of construction-related equipment (e.g., Rolls-Royce Marine, Kongsberg Maritime); 3) equipment supply (e.g., Solberg & Andersen, Grenland, KSI, Proserv); and 4) construction and maintenance of onshore and offshore facilities (e.g., firms from the Aker Group, Aibel, STX, Beerenberg).

Field Development Subsea: This sector includes 96 entities and employs 13,000 people. The segment can be divided into four subcategories: 1) engineering-based design (e.g., Aker Subsea, FMC Production Services); 2) manufacturing, including design and development (e.g., Roxar, Framo Engineering, MPM, FMC), and fabrication of units (e.g., Malm Orstad, Matre Instruments); 3) construction and maintenance (e.g., FMC Kongsberg Subsea, Aker Egersund, Aker Verdal), and 4) maritime-related engineering and services (e.g., Oceaneering, Subsea 7, Deep Sea, Technip, DOF Subsea, Island Offshore Subsea).

Operations Support: This is the second-largest sector with 1,393 entities and employment of 34,000. The sector can be divided into six subcategories: 1) engineering-based services, consisting of firms providing operational support (e.g., Omega, Scandpower) and firms offering personnel for operations support (firms in the IKM Group, Manpower Professional, etc.); 2) manufacturing of equipment for production and safety (e.g., Frank Mohn Fusa, Autronica); 3) equipment supply (e.g., SFF, Scan Tech, Ahlsell Oil & Gas); 4) construction and MMO, consisting largely of firms providing auxiliary services like scaffolding, insulation or painting (e.g., BIS Production Partners, the STS Group); 5) maritime operations, i.e., supply vessels (e.g., Solstad Shipping, DOF, Island Offshore); and 6) support services, such as offshore catering (e.g., Esso Support Services, Sodexo), helicopter transport (e.g., CHC, Bristow), land transport (e.g., SR Transport) and bases (e.g., Norsea base).

Figure 2-6: Total sales in the Norwegian petroleum industry (2008)



Source: Brønnøysund Register Centre, IRIS/BI

As shown in Figure 2-6, total sales from the Norwegian oil and gas industry reached NOK 1,421 billion in 2008. Operators were responsible for more than 70 percent of total sales (NOK 1,033 billion), while suppliers contributed NOK 388 billion to the total figure. Suppliers' total sales were only NOK 57 billion less than the total sales of all operators excluding Statoil.

Case: From steamers, canning and horseshoes to regional offshore supplies and beyond

Many of the firms now viewed as highly specialized 'oil and gas suppliers' did not start out as such. They seized upon the opportunities provided by the initiation of Norwegian oil and gas activities to modify their technologies and become suppliers to a burgeoning new market. Rosenberg Mechanical Workshop was established in Stavanger in 1896. It focused on repairing steamers' boilers and the provision of equipment for the regional canning industry.

The firm soon developed into a shipyard, and, in 1942, it was acquired by the ship-owner Sigval Bergesen d.y., who turned it into a world leader in the construction of large tankers. The company quickly became the largest employer in the city of Stavanger. In 1970, the yard was sold to Kværner (the forerunner of Aker) and, in 1979, it turned toward the offshore industry with the construction of the Statfjord B platform. In the early 2000s, Aker sold off the firm to local investors, who sold it on to Bergen Yards (now Bergen Group) in 2007. Today, Bergen Group Rosenberg is spearheading the Bergen Group's offshore activities. The yard is also contemplating diversifying into the construction of windmills for the renewable energy sector.).

In 1915, Peder Smedvig established a small shipping firm and used the proceeds from that firm to invest in the booming regional canning industry. When oil and gas exploration began in 1965, the Smedvig Group moved into exploration and supply vessels. When the production of oil and gas started in 1973, Smedvig bought its first oil rig. In the 1980s, the Smedvig Group became involved in offshore maintenance and modification (Scana Industries), and in technology development (Smedvig Technologies). Later, at the turn of the century, the Smedvig group started selling off its subsidiaries. Rig management and drilling/well services were sold to the Norwegian investor John Fredriksen, and then served as the backbone for the global groups Seadrill and Seawell. Scana Industries developed into a diversified industrial group and is now listed on the Oslo Stock Exchange. Smedvig Technologies merged with Multi-Fluid to become Roxar, a Stavanger-based world leader in reservoir and subsea technologies. The assets of the Smedvig family are now invested in a private equity firm (Smedvig Capital) and in property (Smedvig Property).

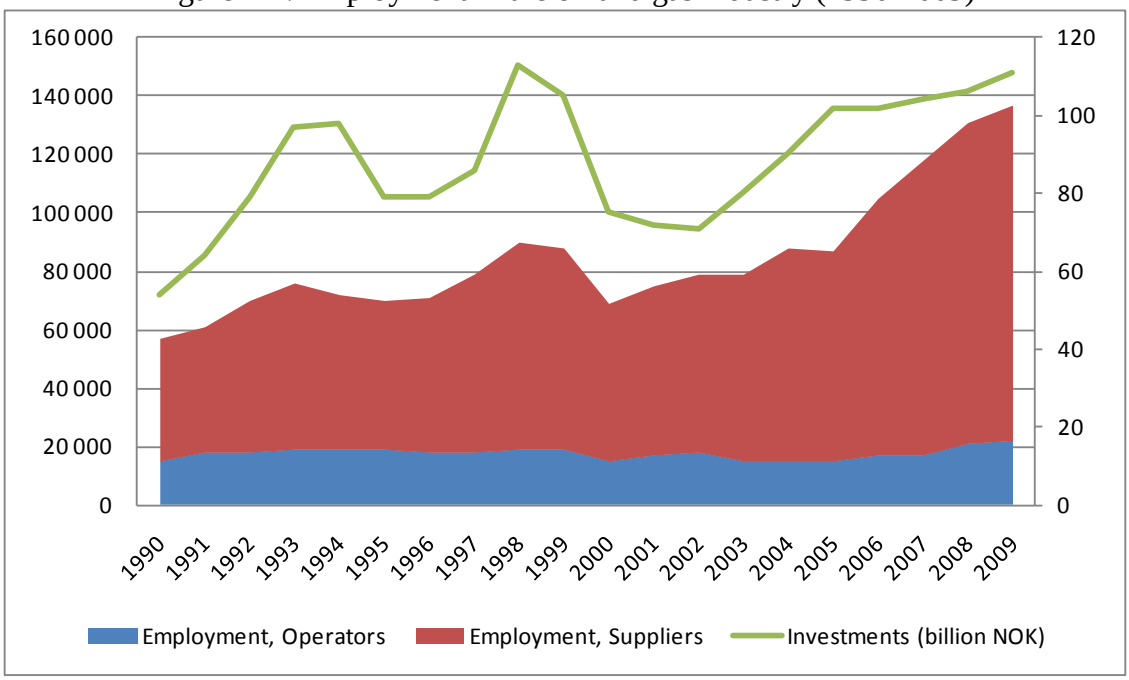
With the mechanization of agriculture in the early twentieth century, Jæren, the predominantly agricultural area south of Stavanger, developed a cluster focused on the manufacturing of agricultural equipment. In the mid-1970s, however, in the face of low-cost competition from abroad, some firms folded, while others turned to new markets (Jøssang 2004). Inge Brigt Aarbakke, for example, who started off in his father's horseshoe workshop, established Aarbakke AS in 1980 with a focus on fabrication assignments from the oil and gas industry. Aarbakke was later bought by HitecVision, a Stavanger-based PE firm and, over a period of 10 years, the firm's sales increased ten-fold. Malm Orstad at Klepp near Stavanger started out after WWII as a local smithy making loading trays for tractors. In the late 1980s, the company began to orient itself towards fabrication for the oil and gas industry. Today it is a trusted supplier of manufacturing services for firms in drilling and subsea. Many of these firms are now considering other markets. Aarbakke has looked into medical supplies, such as prostheses. GMV, another agricultural supplier turned oil and gas supplier, is looking into equipment for tidal energy plants.

2.2 Historical development of employment

From the very beginning of the Norwegian oil and gas adventure, there have been discussions on how to properly gauge the size of the industry. The Norwegian authorities realized early on that confining their definition of the industry to activities registered under either NACE code 06 (operators) or 09.1 (support activities) would leave out the large number of important suppliers that are registered using NACE codes different from the 'oil and gas codes', e.g., yards constructing platforms and owners of supply vessels.

From 1973 to 2003, the Norwegian Agency for Employment (Aetat) provided annual surveys of petroleum-related employment based on a population of petroleum-related firms developed with the assistance of local employment offices. In 2003, the final year in which these surveys were published, Aetat collected data from 800 firms, which employed a total of 76,608 people (2007). In the same year, total employment in activities registered under NACE codes 06 and 09.1[10] was only 28,775. Figure 2-7 combines employment data from Aetat (up until 2002) [11] and employment data for the firm population established for this project (starting in 2003).[12]

Figure 2-7: Employment in the oil and gas industry (1990-2009)



Sources: employment: 1990-2002 (Aetat) and 2003-2009 (IRIS/BI); investments: Norwegian Petroleum Directorate

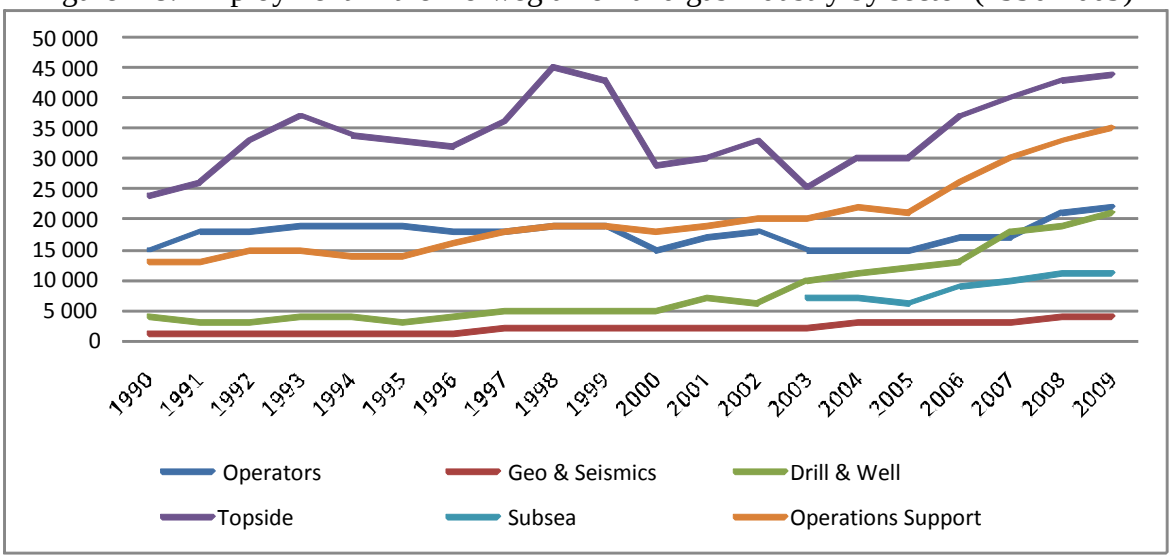
As the figure illustrates, employment in the industry has more than doubled over the past twenty years. As employment among operators remains almost constant at around 20,000, the growth can be attributed, in its entirety, to the supplier industry. The figure also shows how employment in the supplier industry fluctuates with investments on the Norwegian shelf.

[10] The NACE codes were revised in 2007. The NACE codes corresponding to 06 and 09.1, were in 2003 11.1 and 11.2, respectively.

[11] Following Vatne (2007), employment figures from Aetat contributed by 'generic' firms are left out, i.e., public administration of the sector and R&D institutes.

[12] It should be noted that because the firm population has been developed over the last few years, it may not include firms that are no longer in existence due to mergers, acquisitions or bankruptcies.

Figure 2-8: Employment in the Norwegian oil and gas industry by sector (1990-2009)



Sources: 1990-2002 (Aetat) and 2003-2009 (IRIS/BI)

To understand the drivers of the changes in employment, it is necessary to study the development of employment in the different sectors over time. In this respect, Figure 2-8 illustrates employment from ten relevant categories used in the Aetat surveys, which are grouped according to the six sectors used in the IRIS/BI project.[13]

The graph shows that the employment peaks of the 1990s (1993 and 1998) were both related to the construction of platforms and rigs (Topside). Following a slump in 1999, employment in Topside is now back to roughly the same level as in 1998. As this sector is very vulnerable to low-cost competition from abroad (ECON 2010), the current growth may be due to maintenance and modification activities that, by their very nature, must be conducted in-country. Subsea was not included as a separate sector in Aetat's surveys, where its employment was most probably included in Topside. The inclusion of Subsea as of 2003 may, therefore, explain the drop in Topside employment from 2002 to 2003.

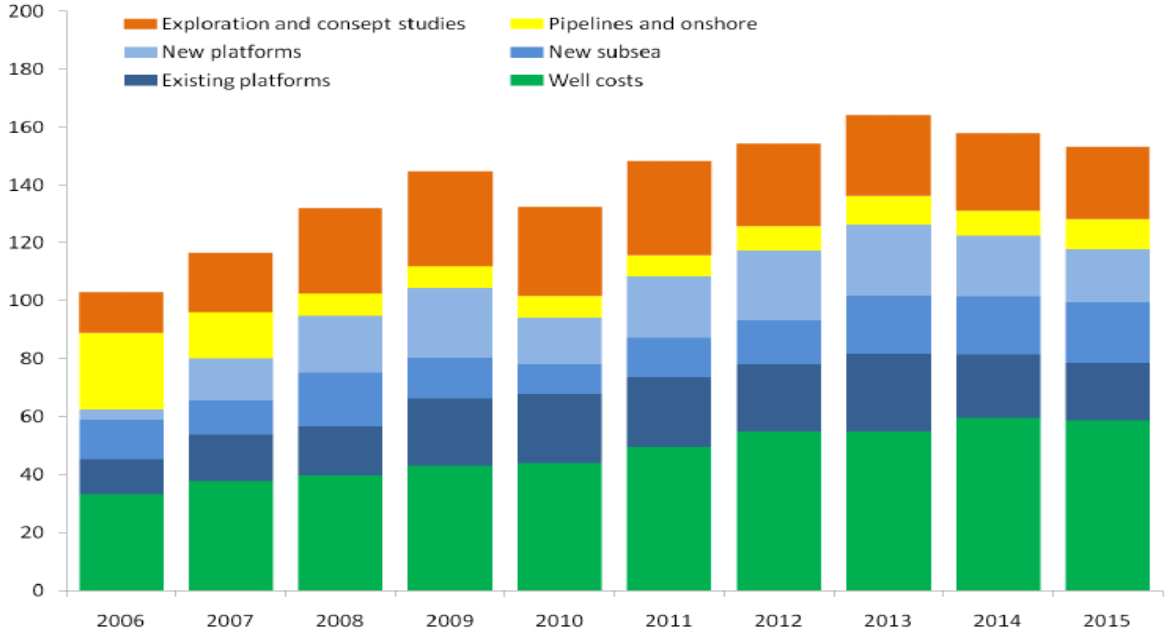
Two notable growth sectors are Drill & Well and Operations Support. A large part of this growth may be the result of the increased focus on MMO and the increasing internationalization of the industry (especially in Drill & Well) in recent years. ECON (ECON 2010) estimates that the share of employees engaged in international operations is about 50 percent within Drill & Well and 40 percent in Operations (roughly similar to 'Operations Support' here).

[13] The 10 relevant sectors from Aetat's survey are grouped according to the six sectors used in this report as follows: operators are grouped as Operators; drilling firms are grouped as Drill & Well; 1/3 of transport and shipping firms are grouped as Geo & Seismics, and 2/3 of transport and shipping firms are grouped as Production; manufacturing and construction, and engineering are grouped as Topside; and service firms, bases, catering, operations of onshore facilities, and sundry goods and services are grouped as Production.

2.3 Production on the NCS – present and future

The activity level on the NCS is currently very high. Total annual investments in the sector are expected to rise from approximately NOK 130 billion in 2010 to around NOK 150 billion in 2015 (Figure 2-9).

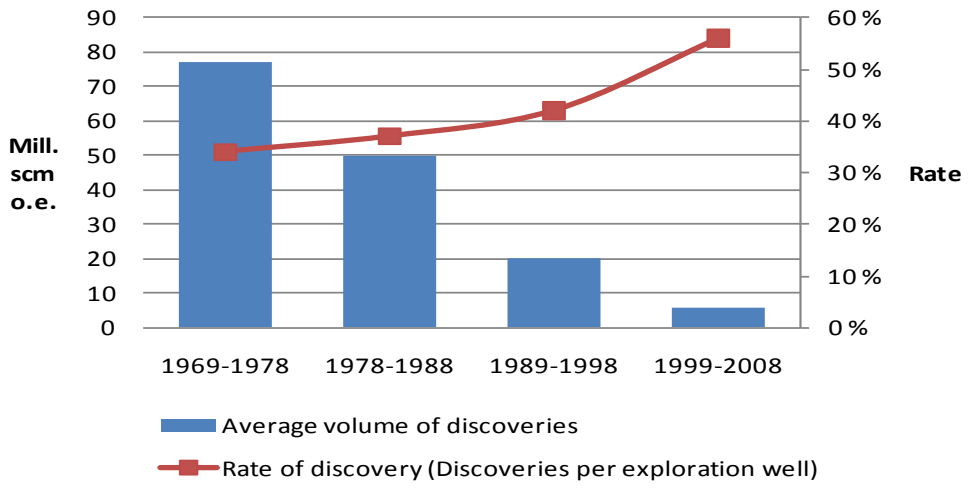
Figure 2-9: Investments on the NCS (2006-2015)



Source: Norwegian Petroleum Directorate

Activity is high in both exploration and production wells on the NCS. Figure 2-9 shows that well costs make up the largest part of the oil and gas investments. Modifications of existing platforms are expected to rise until 2013, after which they are likely to decline somewhat. Investments in subsea installations will remain high, while investments in new platforms will decline somewhat starting in 2014. Investments in pipelines, onshore facilities and exploration will remain at levels similar to those seen in the last few years.

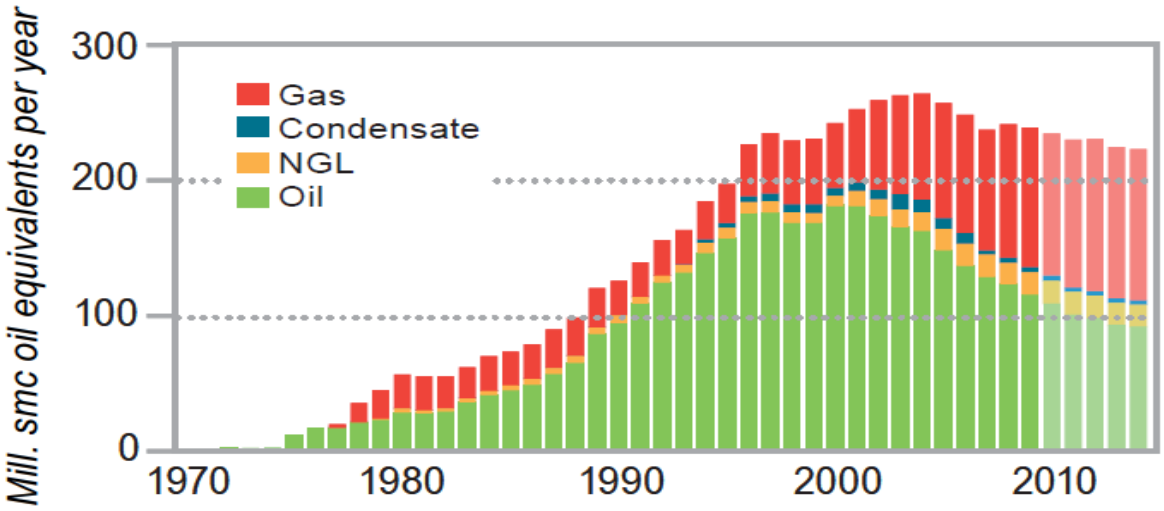
Figure 2-10: Average volumes of discoveries and rates of discovery (1960-2008)



Source: Norwegian Petroleum Directorate

Figure 2-10 shows that while the rate of discovery (i.e., discoveries per exploration well) has risen dramatically since 1969, the average volume of discoveries has decreased drastically. This trend is reflected in the forecast of a decline in production on the NCS.

Figure 2-11: Historical oil and gas production and forecast (1970-2015)



Source: Norwegian Petroleum Directorate (2010a)

Figure 2-11 shows that the production of oil and gas from the NCS peaked in 2004 and has since been declining slowly. The production of oil is predicted to continue to fall, while the production of gas is expected to increase at least through 2015.

The current discussion regarding the expected drop in production revolves around three issues: improving the rate of recovery, increasing the number of production wells and, possibly, opening new areas ('new acreage') to oil and gas activity.

Improving recovery

Oil and gas exploration on the NCS is technologically advanced with an average rate of recovery of 46 percent for oil (Ministry of Petroleum and Energy 2010), which is approximately 11 percentage points above the global average (International Energy Agency 2005). Despite this impressive figure, there is a strong focus on improved recovery.

> "Although our rate of recovery is among the best in the world, we are still not satisfied. If we manage to recover just one percent more, this would mean revenues in the hundreds of billions for Norway." Bente Nyland, NPD Director General

At the end of 2010, a government-appointed commission ('the Åm commission') presented a number of concrete proposals for improved recovery (Ministry of Petroleum and Energy 2010). First, the government should refashion the regulatory regime so that it promotes and rewards effort for improved recovery. Second, the Ministry of Petroleum and Energy and the industry should initiate a joint effort to reduce costs. Third, the government should ensure collaboration between the different licensees in improving recovery on the mature fields. Fourth, the government should promote research and innovation related to improved recovery. Fifth, the industry should focus on simpler well designs, new injection technologies,

integrated operations, better reservoir characterization and more cost-efficient subsea solutions. Finally, the industry should promote science based education.

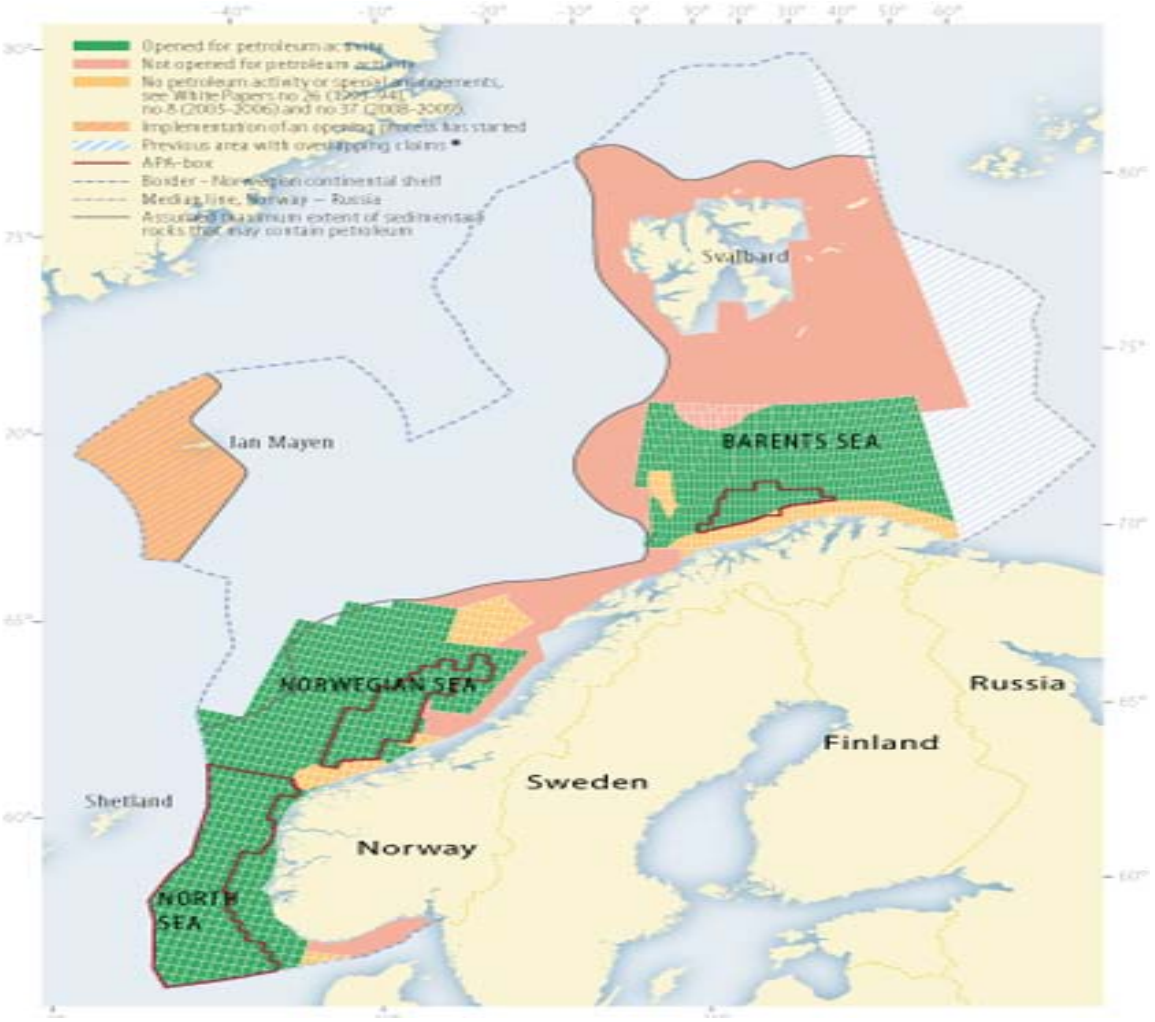
Increasing the number of production wells

The Åm commission (Ministry of Petroleum and Energy 2010) notes that the focus on exploration may have diverted attention from fields in operation. Furthermore, when presenting the 2010 annual report on activity on the NCS,[14] the NPD documented an increase in exploration wells relative to production wells, and urged licensees to drill all planned production wells and to improve the rate of recovery by developing discoveries in currently producing fields.

New acreage for oil and gas activity

Even though production on the NCS has peaked, considerable reserves remain. Current plans indicate that some of the large fields will be producing oil and gas for many more decades. The giant Ekofisk field will be producing till at least 2050, Gullfaks and Draugen are expected to be producing until at least 2030, and the Statfjord field will be producing until at least 2020 (Norwegian Petroleum Directorate 2010a).

Figure 2-12: Area status on the Norwegian continental shelf

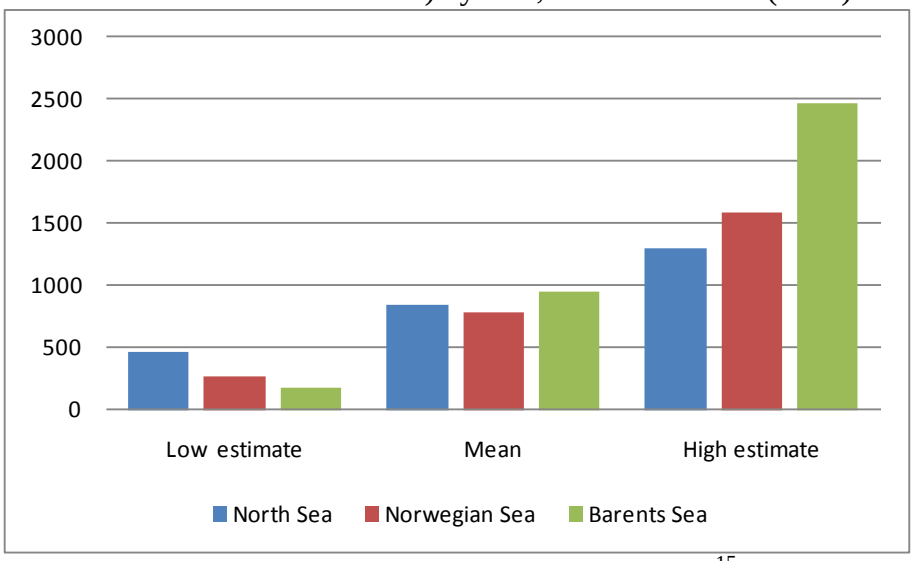


Source: Norwegian Petroleum Directorate (2010)

[14] http://www.npd.no/en/news/News/2011/The-shelf-2010--Press-releases/#

Estimates of future NCS production take both areas opened for oil and gas activity, and areas not opened into account. Figure 2-12 shows that areas currently not opened for oil and gas activity are primarily located in the Norwegian Sea and the Barents Sea. For the areas around Jan Mayen, an opening process has been initiated. The maritime border between Norway and Russia in the Barents Sea was the subject of a dispute, but an agreement has now been reached and is awaiting ratification. However, for both of these areas (Jan Mayen and the maritime border with Russia), seismic surveys are lacking, so there are no estimates of available resources in these areas. A report on a possible opening of the unopened areas in the northern part of the Norwegian Sea (the areas off Lofoten, Vesterålen and Senja) indicates that these areas could hold 202 million scm o.e. (approximately. 1.4 billion barrels) (Norwegian Petroleum Directorate 2010b).

Figure 2-13: Estimates of undiscovered resources on the NCS (excluding Jan Mayen and the maritime border with Russia) by area, million scm o.e. (2010)

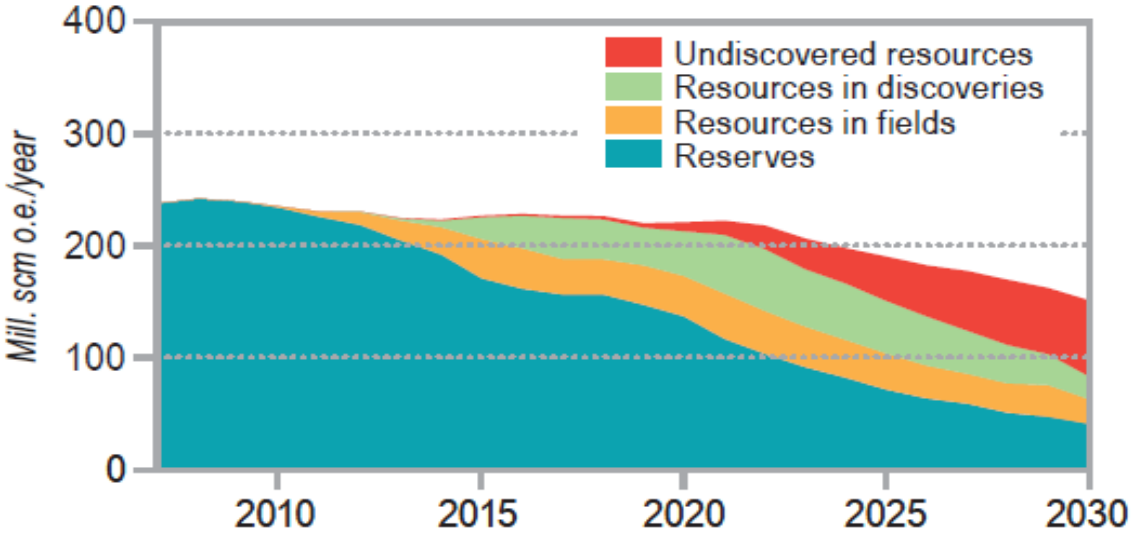


Source: Norwegian Petroleum Directorate[15]

The figure above shows low, high and mean estimates for current undiscovered resources on the Norwegian continental shelf. Disappointing exploration results in 2010 led the Norwegian Petroleum Directorate to reduce its estimates of undiscovered resources in the Norwegian Sea. However, with the exception of the low estimates, the Norwegian Sea and the Barents Sea combined are expected to hold more undiscovered resources than the entirety of the North Sea.

[15] http://www.npd.no/en/news/News/2011/The-shelf-2010--Press-releases/The-shelf-2010--Undiscovered-resources/

Figure 2-14: Production forecast NCS, opened and non-opened areas (2007-2030)



Source: Norwegian Petroleum Directorate (2010a)

Figure 2-14 illustrates the production forecast for the NCS based on estimated reserves in opened and unopened areas for which good seismic data exists. In other words, the figure excludes the areas around Jan Mayen and areas along the maritime border with Russia in the Barents Sea. The graph shows that future oil and gas production will depend on currently undiscovered resources and undeveloped resources in existing discoveries and fields.

As production forecasts include estimated reserves in areas currently not opened for oil and gas activity, it follows that the actual production will depend on the outcome of the current Norwegian political debate on the opening of areas in the Norwegian Sea.

2.4 Summary

Although it started from modest beginnings as a producer of oil and gas in 1971, Norway had become the worlds' 13th largest producer of oil and its fourth-largest producer of natural gas in 2009. The Norwegian oil and gas industry was built upon established Norwegian competences in mining (geophysics), maritime operations and maritime construction (yards), with invaluable inputs from foreign operators and suppliers. At present, the industry is a complete cluster of 136,000 employees divided into several sectors: Operators (22,000), Geo & Seismics (4,000), Drill & Well (20,000), Topside (43,000), Subsea (13,000) and Operations Support (34,000). The value creation from operators and suppliers combined represents one-third of total Norwegian GDP (2008).

Employment in the oil and gas industry has been steadily increasing but has fluctuated with the level of investments. Currently, the activity level on the NCS is high. Investments on the Norwegian shelf are at an all-time high, with planned investments for 2011 at NOK 135 billion (Norwegian Petroleum Directorate). Investments in new offshore installations are decreasing, while investments in drilling and well and in the maintenance and modification of existing installations are increasing. While the rate of discovery (discoveries per exploration well) has increased, the average size of discoveries has declined. Production on the NCS peaked in the mid-2000s and is now expected to gradually decline. This development has led to a focus on improved recovery, and on the possibility of opening new areas for oil and gas production.

3 Cluster Attractiveness

This chapter discusses the degree to which the Norwegian oil and gas cluster is attractive. In particular, we assess the degree to which it encompasses all relevant activities, i.e., its completeness, the existence of a critical mass of firms in all parts of the oil and gas industry activity system, its value-creation properties and its geographical distribution.

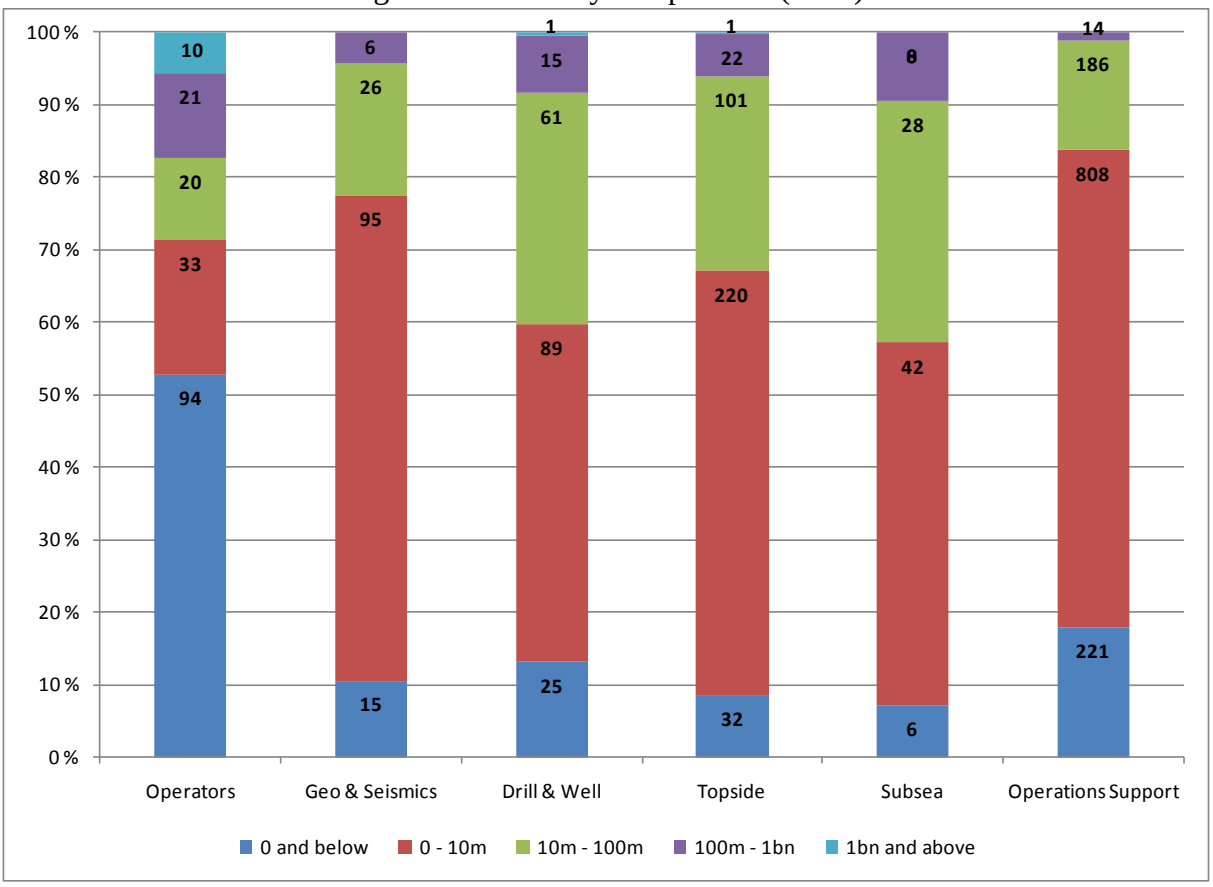
3.1 Cluster completeness

The completeness of a cluster depends on the distribution of companies along the important parts of the value chain, particularly in terms of whether there is a healthy distribution of larger and smaller companies. The degree of completeness also depends on the knowledge base and diversity of the cluster as a whole.

3.1.1 Distribution among larger and smaller companies

An investigation of the completeness of the Norwegian oil and gas industry reveals a well-developed industry. However, several discrepancies are worth noting.

Figure 3-1: Industry composition (2008)



Sources: Brønnøysund Register Centre, IRIS/BI

Figure 3-1 shows the composition of firm revenue in the Norwegian oil and gas industry by sector. Numbers in the vertical columns represent the number of firms in each bracket. The industry, which comprises 2,500 firms, is diverse. All sectors have a critical mass of firms competing to strengthen the cluster as a whole. Especially noteworthy is the existence of non-revenue startups in all sectors, which provides evidence of growing diversity and continued innovation.

An examination of the sectors is also enlightening. The sector with the highest number of high-revenue firms is Operators. Ten firms in this sector had revenues of more than NOK 1 billion in 2009 and two of these had revenues of more than NOK 100 billion. There is a wide diversity of firms in the smaller revenue groups and there is an unusually high number of firms with no revenue (over 50 percent of the total number of firms in the sector). This latter characteristic is probably due to the arrangement that grants operators without income streams a refund of 78% of all exploration costs.

70 percent of Geo & Seismics firms fall into the NOK 0–10m revenue bracket. As niche providers of knowledge, these smaller firms provide a strong base for competence development and technological innovation. There is diversity among the larger firms as well but the sector lacks a selection of high-revenue firms similar to those present in most other sectors.

Drill & Well has one of the largest shares of mid-sized firms in the industry. The sector is supported by a large share of high-revenue firms and a high number of startup firms, both of which indicate a dynamic nature.

Topside is the second-largest sector in terms of the number of firms. The sector is dominated by mid-sized firms but there is still a fair number of large firms.

Subsea is the smallest and youngest one. The composition of firms in this sector is well diversified, although the very large firms are missing. In the future, consolidation might be evident this sector. Currently, however, the presence of a substantial number of medium-size firms stimulates a healthy rivalry.

Operations Support is, by far, the largest sector in terms of the number of firms. However, it is also the sector with the lowest score for technological leadership of local and, to some extent, national suppliers when compared to international suppliers (see section 10).

In 2003, AFF (Administrative research fond at the Norwegian School of Economics and Business Administration) studied executive perceptions of the level of technological competence in three oil and gas hubs: Houston, Norway and the UK (AFF 2003).[16] With regards to technological competencies among operators, the study found that Houston was ranked first, with Norway a close second. With regards to technological competencies among suppliers, Norway was ranked first, while Houston was ranked second. This corresponds to Table 2-1, which shows that the Norwegian supplier industry is active in all sectors of the oil and gas industry and, in each sector, covers a number of technical activities (engineering-based services, manufacturing, equipment supply, maritime operations, etc.).

The AFF report notes one deficiency in the Norwegian oil and gas cluster – lack of access to easily available and correctly priced capital for innovation. Our interviews, however, indicate that this situation has improved over the last ten years.

Within the equity market, national financial players, such as pension funds, private equity (Hitec Vision) and venture capital firms (e.g., Energy Ventures, Progressus Management), have emerged. Furthermore, the debt market has become more sophisticated, both in terms of

[16] The report also included Libya as a point of reference but it was not deemed a 'hub' per se.

banks' insights into the workings of the industry and in terms of services provided – there has been an increasing amount of securitization and brokerage services.

> "As of now, no serious oil and gas supplier should have problems with the access to capital." Senior executive, Norwegian finance institution

There is though, a clear dichotomy related to size, with smaller oil and suppliers being served by regional finance institutions, and the larger ones being served by national institutions or a combination of national, regional and international institutions.

> "Local finance institutions are very important in the entrepreneurial phase, but many oil and gas suppliers outgrow them and need to turn to national institutions." CEO, Rogaland (oil and gas supplier)

> "The larger companies within the oil and gas sector are heavily dependent on foreign banks. But this is to a large extent explained by the simple fact that Norway is a small country." Senior executive, Norwegian finance institution

The anecdotal evidence provided here indicates that the last ten years have seen an improvement in terms of both access to capital and quality of financial services provided. However, for the larger companies, there is still a wide spread dependency on international finance institutions. As the Norwegian cluster has become a hub for almost all of the technical disciplines of the oil and gas industry, one would assume that it would also be a hub for foreign financial institutions. Although these services can be procured form abroad, the lack of geographically close access could hamper firms that have grown beyond their initial entrepreneurial phase.

3.2 Economic characteristics – earnings and costs

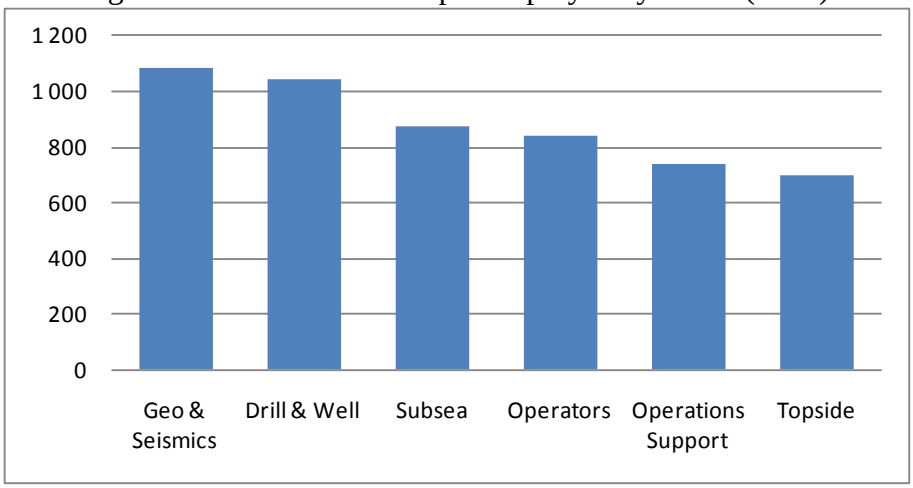
This section looks at the economic characteristics of the oil and gas industry, and shows that an economically attractive supplier industry implies higher costs for the operator side of the industry.

Earnings

Is the Norwegian oil and gas industry economically attractive? Are all of its parts equally attractive? The different parts of the Norwegian oil and gas industry have distinct economic characteristics in terms of profit margins (EBIT[17]-margins) and salaries. As a proxy for salaries, personnel costs will be used, but it must then be kept in mind that these numbers include employer taxes and pension contributions.

[17] EBITDA = Earnings Before Interest and Taxes

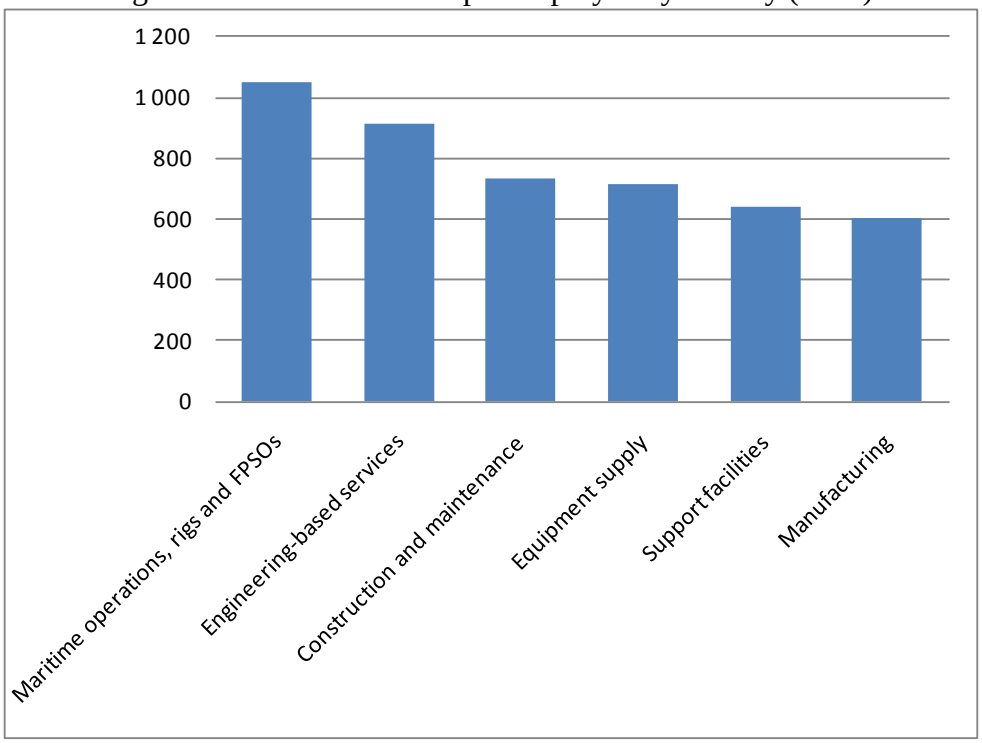
Figure 3-2: Personnel costs per employee by sector (2009)



Sources: Brønnøysund Register Centre, IRIS/BI

Figure 3-2 shows personnel costs per employee in 2009 in the different sectors. The figure shows that these costs are highest in Geo & Seismics and Drill & Well, and lowest in Operations Support and Topside.

Figure 3-3: Personnel costs per employee by activity (2009)

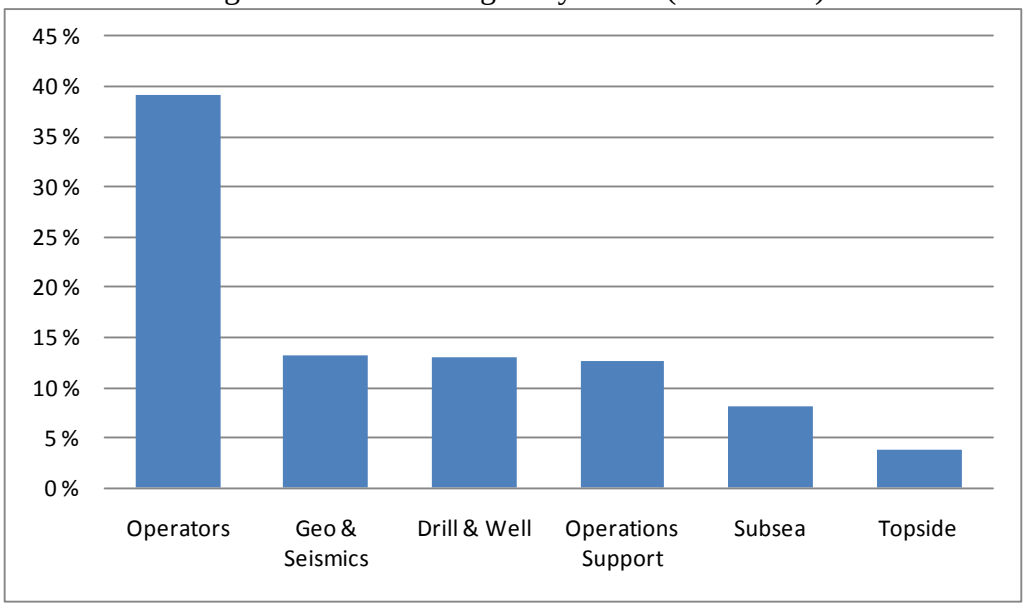


Sources: Brønnøysund Register Centre, IRIS/BI

Figure 3-3 shows personnel costs per employee for 2009 in thousands NOK in the different industry activities. The highest personnel costs are found in maritime operations, rigs and FPSOs, and in engineering-based services. The lowest costs are in support facilities and manufacturing. The relatively high personnel costs in the engineering-based services (e.g., Halliburton, BakerHughes) and the maritime parts of the industry (e.g., Seadrill, Solstad) are due to the use of highly skilled personnel (employees with apprentice certificates or engineers) and the need to pay offshore benefits. The lowest personnel costs either occur in

activities where no offshore benefits are paid (manufacturing) or in activities with relatively few highly educated workers.

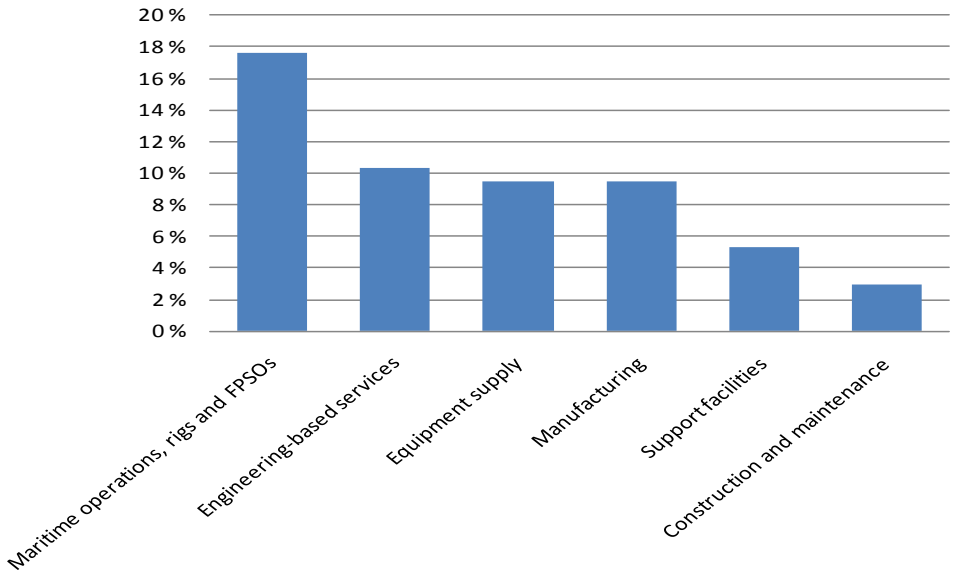
Figure 3-4: EBIT-margins by sector (2005-2009)



Sources: Brønnøysund Register Centre, IRIS/BI

Mean profit margins (EBIT-margins) from 2005 to 2009 are calculated in order to account for fluctuations from year to year resulting from shifts in supply and demand. Figure 3-4 shows that the mean profit margin for Operators is almost 40 percent, which is significantly higher than the margins in all other sectors. For suppliers, margins are the highest in Geo & Seismics, Drill & Well and Operations Support. Topside reports the lowest margin at 4 percent.

Figure 3-5: EBIT-margins in supplier industry by activity (2005-2009)



Sources: Brønnøysund Register Centre, IRIS/BI

If supplier firms are divided according to activity (Figure 3-5), the highest operating margins are found in maritime operations, rigs and FPSOs, while the lowest are found in support facilities and in construction and maintenance. The extremely high margins in maritime operations, rigs and FPSOs point to the fact that when the industry booms, the availability of vessels and rigs tends to become a bottleneck and their rates skyrocket. The low margins for support facilities and for construction and maintenance are due to the extreme competition in this part of the industry.

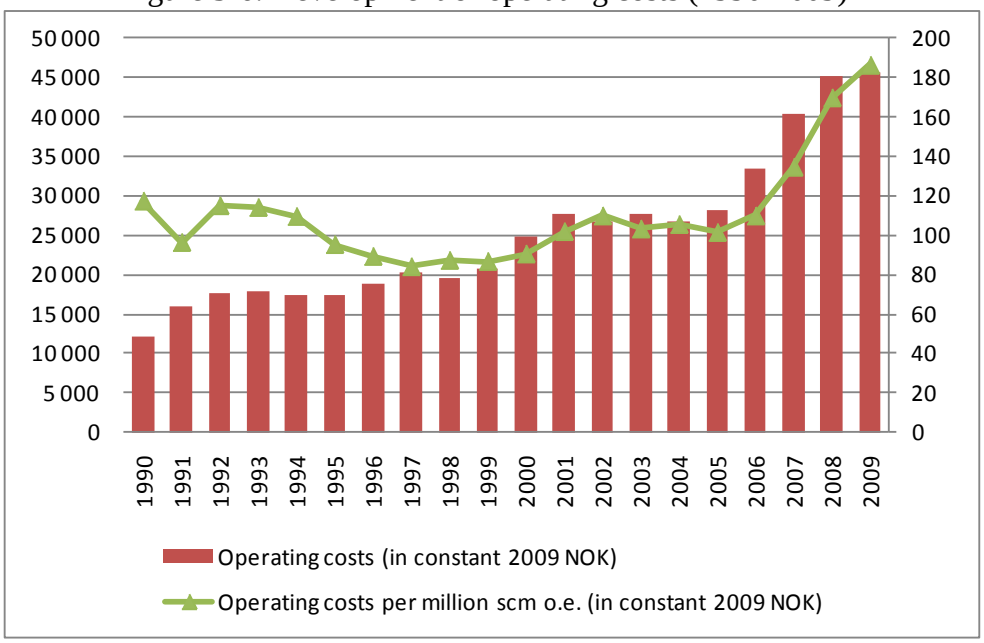
Costs

The flip side of the high earnings for personnel and capital employed in the supplier side of the oil and gas industry is that costs for operators rise. Furthermore, the Norwegian shelf is known as a high-cost environment. The high costs have a number of implications.

First, Norwegian yards find it increasingly difficult to cope with foreign competition in the construction of large offshore installations (ECON 2010). Many yards are, therefore, redirecting their activities towards maintenance and modification, while those that stay in the construction business tend to rely on imports of foreign personnel. Second, the labor-intensive mechanical manufacturing within the Drill & Well and Subsea sectors is facing an increasingly tough environment given the technological catch-up activities evident among low-cost Asian suppliers (Noreng 2005). Third, the increasing costs in the supplier industry affect the profitability of field development (Konkraft 2004).

> "Standardized mechanical manufacturing has no future in Norway. Norwegian manufacturers have to focus on prototype development and just-in-time deliveries based on state-of-the-art equipment and the best operators that can be found." CEO, oil and gas supplier

Figure 3-6: Development of operating costs (1990-2009)*



Source: Norwegian Petroleum Directorate

Figure 3-6 shows the development of total operating costs and operating costs per million scm oil equivalents from 1990 to 2009 expressed in constant 2009 million NOK. From 1997 to

2009, operating costs per million scm o.e. increased from NOK 84 million to NOK 186 million, or by 122%. This increase poses a significant challenge for production on the Norwegian shelf.

> "The commission recognizes that a reduction in the costs on the Norwegian shelf is imperative for improved recovery, and that this will be a challenging process requiring a joint effort from public authorities and the industry." The Åm Commission on Improved Recovery (Ministry of Petroleum and Energy 2010).

The rising costs, coupled with falling size of new discoveries, require that field developments on the NCS become more standardized.

> "The challenge is developing the smaller fields in an economically sound way. Tailor-made solutions will be too expensive. We need to find standardized 'quick-fix' solutions. In this area, a lot of innovation work is needed." CEO, medium-sized operator

> "To develop smaller discoveries in an economically sound way, we have established a 'fast-track' program to accelerate production and save costs. Field development will be 'industrialized' using the concept of 'subsea tie-in' to existing installations. It is hoped that this will help cut costs by 30 percent and lead to fields being developed two years after the exploration rig leaves the site." Statoil (presentation at the Offshore Strategy Conference, 2011)

3.3 Value creation

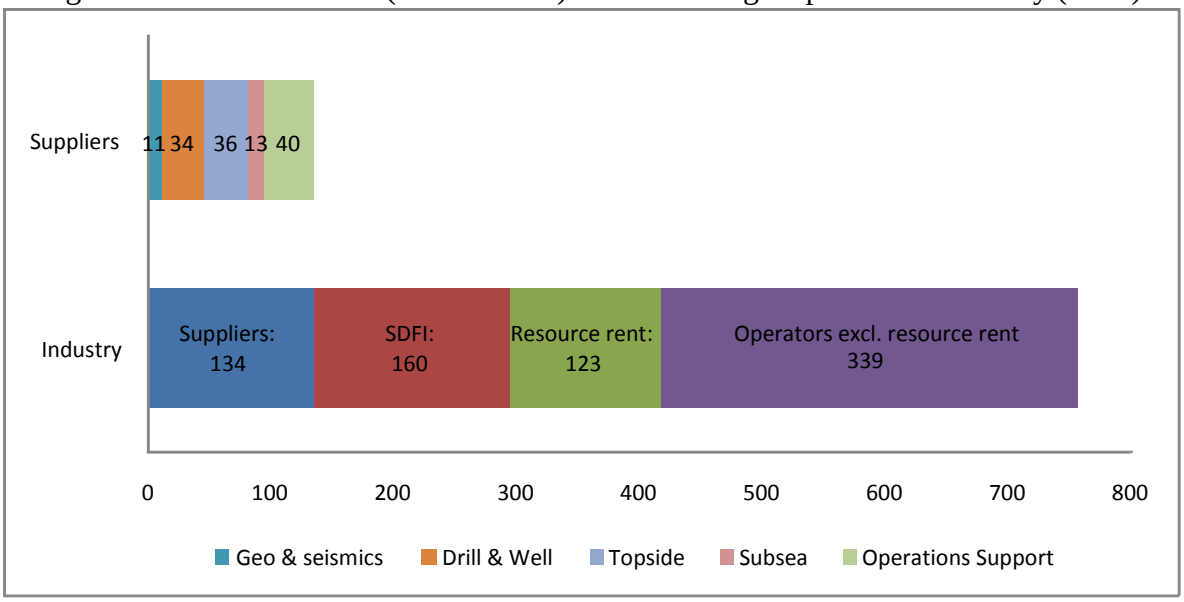
The *value creation* of a given firm is defined as the economic resources it creates for distribution among its employees (salaries), capital owners (capital yield net of taxes) and the government (taxes on labor and capital).[18] A comparison of the economic performance of suppliers and operators is, perhaps, futile, as the respective business models vary widely. While suppliers make money exclusively from employing their personnel and capital to provide goods and services, operators make money from the licenses they hold to exploit a natural resource. Therefore, they share in the resource rent. As operators base their activities on the exploitation of a natural resource, their before-tax capital yield includes the yield of the natural resource, which is known as the 'petroleum rent'. The Norwegian regulatory regime views the petroleum resource and, thus, the petroleum rent as state property. It therefore levies a special petroleum tax of 50 percent on all production income derived from the NCS. When applied over a sufficient number of years, the petroleum tax is supposed to claw back the 'petroleum rent'.

Figure 3-7 shows that, when using the definition of the supplier industry utilized in this study, the Norwegian oil and gas industry's value creation (excluding capital yield from foreign subsidiaries) was NOK 756 billion in 2008. In the same year, total Norwegian GDP[19] was NOK 2,266 billion. Therefore, in 2008 the oil and gas industry constituted almost exactly one-third of total Norwegian GDP, i.e., six percentage points more than when a more limited definition of the supplier industry is used Figure 2-3).

[18] A firm's value creation may be approximated as: earnings before interest and taxes (EBIT) + depreciation + amortization + personnel costs.

[19] This figure is measured at basic prices and, given the definition of GDP, excludes yields from capital invested in foreign subsidiaries.

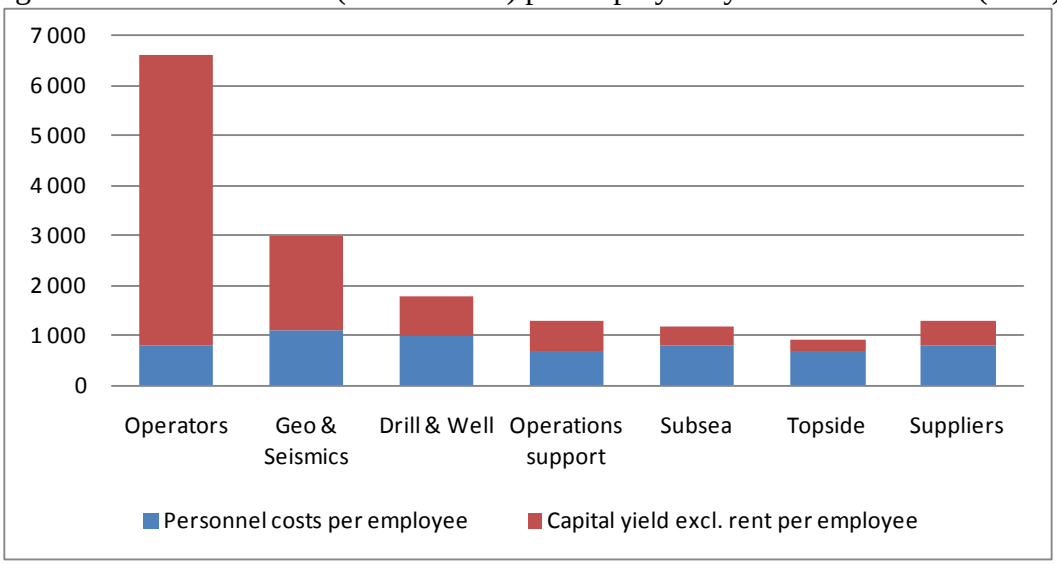
Figure 3-7: Value creation (billion NOK) in the Norwegian petroleum industry (2008)



Sources: Brønnøysund Register Centre, IRIS/BI

The value creation of oil and gas extraction in 2008 (NOK 622 billion (www.ssb.no)) is divided into three parts: a) net income from the SDFI;[20] b) petroleum rent, calculated as 50 percent of the average capital yield among Operators from 2000 to 2008; and c) capital yield among Operators excluding petroleum rents. Value creation from the supplier industry was NOK 134 billion, which is 40 percent of the capital yield from Operators when petroleum rents are excluded.

Figure 3-8: Value creation (billion NOK) per employee by source and sector (2008)



Sources: Brønnøysund Register Centre, IRIS/BI

Figure 3-8 shows value creation per employee among Operators (excluding the estimate of petroleum rents calculated above) and suppliers divided by source (personnel and capital) in 2009. The figure shows that value creation from personnel is relatively high in all six sectors.

[20] Statens Direkte Økonomiske Engasjement (SDØE).

Among suppliers, average value creation is NOK 1.2 million. Value creation from capital is the highest in Geo & Seismics and in Drill & Well due to the capital intensity of these sectors (vessels and rigs). Value creation is the lowest in Operations Support and in Topside. The difference in value creation per employee between operators and suppliers is attributable to the larger capital yield for operators. This may partly be due to the fact that operators have higher capital intensity than suppliers but it also reflects the fact that the capital yield still includes parts of the petroleum rent.

3.4 Internationalization

Exports of oil and gas from Operators working on the NCS totaled NOK 476 billion in 2009 and constituted 46 percent of total Norwegian exports. Additional export income was attained through the international operations of the Norwegian supplier industry.

Table 3-1: Foreign market shares, Norwegian-based oil and gas suppliers (2009)

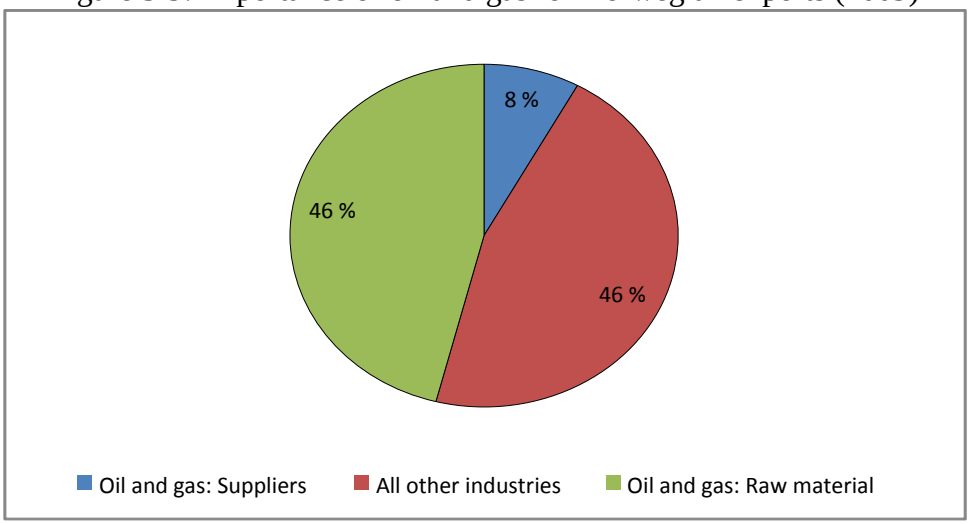
	Size of market (NOK billion)	**Market share of Norwegian-based supplier firms (%)**
North Africa and the Mediterranean	7	28
UK and the North Sea (beyond the NCS)	47	24
Southeast Asia, India and Australia	191	17
West Africa	105	12
Brazil, Venezuela and Mexico	82	12
China	30	11
US and Canada	138	8
Russia, Azerbaijan and Kazakhstan	48	8
Middle East	107	2

Source: Fjose et al. (2010b)

Experience gained from work on NCS projects has translated into considerable activities abroad for Norwegian oil and gas suppliers, and the Norwegian supplier industry has gained significant footholds in important foreign markets (Table 3-1). As with the measurement of employment, the measurement of foreign sales of oil and gas suppliers is fraught with difficulties. The income resulting from Norwegian firms supplying abroad goods produced in Norway or providing services through firms based in Norway is registered as export income. However, the income of foreign operations of Norwegian subsidiaries is not included in Norwegian accounts and is only reported as a share of operations surplus from abroad. Therefore, given the increasing use of sales through foreign subsidiaries (Bjorvatn *et al.* 2007), relying on export income figures will lead to an underestimation of the size of foreign operations.

Figure 3-9 shows that exports from oil and gas suppliers were 8 percent of total Norwegian exports in 2009. Total sales abroad for Norway-based firms in 2009 are estimated at around NOK 120 billion (ECON 2010; Fjose *et al.* 2010b). Fjose et al. (2010b) divide foreign sales into traditional exports (70 percent of total sales abroad) and sales through foreign subsidiaries (30 percent of total sales abroad). If we use these estimates, the exports of Norwegian oil and gas suppliers represent a 15% share of total exports, excluding sales of oil and gas.

Figure 3-9: Importance of oil and gas for Norwegian exports (2009)



Source: Menon (2010), Statistics Norway (2010)

To assess how far the different sectors of the industry have come in terms of internationalization, the survey conducted for this project asked respondents about the share of foreign sales. However, as respondents were not asked to distinguish between exports and sales through foreign subsidiaries, some firms may have reported the share of exports, while others may have reported the group's foreign sales. Therefore, the conclusions that may be drawn from this source of information are limited.

Table 3-2 shows that the share of foreign sales among the 350 firms surveyed averaged 32 percent in 2009. This is in line with the Menon Business Economics (Fjose *et al.* 2010b) and ECON (2010) findings of 34[21] and 40 percent, respectively. The share of foreign sales is highest in Geo & Seismics, Drill & Well and Subsea, and lowest in Topside, indicating that the latter is basically a home-market industry.

Table 3-2: Foreign sales per sector and activity (2010)

	Engineering-based services (NACE 06, 09, 58-74, 78-82)	**Manufacturing (NACE 22-28)**	**Equipment supply (NACE 46, 77)**	**Construction maintenance (NACE 30-33)**	**Maritime ops., rigs, FPSOs (NACE 50 ++)**	**Support facilities (NACE 38, 49, 52, 56)**	**Total**
Geo & Seismics	38%				42%		**39%**
Drill & Well	32%	43%			84%		**39%**
Topside	21%	26%	6%	26%			**22%**
Subsea	50%	39%		25%	30%		**38%**
Operations Support	32%	39%	17%	42%	66%	19%	**33%**
Total	**32%**	**36%**	**16%**	**30%**	**62%**	**19%**	**32%**

Sources: IRIS/BI Survey

[21] Menon finds total foreign sales of 49 percent and estimates that 70 percent of these are exports, i.e., exports are 34 percent (49 percent x 70 percent).

When the respondents are grouped according to activity, the share of foreign sales is by far the highest in maritime and rig activities (62 percent). The second-highest share is in manufacturing (36 percent), which is, to a large extent, explained by manufacturing for Drill & Well, i.e., the NODE cluster in southern Norway, but it also the result of the design and fabrication of subsea equipment in western Norway (e.g., Framo Engineering in Bergen). Engineering-based services have combined foreign sales of 35 percent. The share is highest in engineering related to Subsea (50 percent) and lowest in engineering related to Topside (21 percent). The relatively low share of foreign sales in engineering-based services implies that many of these activities occur in the home market. The same is true for support facilities (19 percent) and equipment supply (16 percent). These activities, which must be done 'on location', may face significant challenges when attempting to internationalize. They may be forced to cease operations if the NCS activity level declines.

> "When the waters off of Norway are drained, it is doubtful that we will still be present in Norway!" CFO, global oil service firm

Given the current level of oil and gas investments on the NCS, the parts of the industry that rely on the home market appear likely to have some comfortable years ahead of them. The shares of foreign sales shown in Table 3-2 provide important information as to which parts of the industry may be able to internationalize their activities (engineering-based manufacturing, maritime operations, rigs, etc.) and which would be most likely to wither away with the end of oil and gas activity on the NCS (construction, maintenance, equipment supply and support facilities). There are a number of reasons for concern. First, the parts of the industry with the lowest shares of foreign sales (Topside, Equipment Supply and Support facilities) employ 53,000 people. Second, even if internationalization proves successful, the use of Norwegian personnel will most probably be lower than when the activities were handled in Norway.

> "When we go abroad, we bring engineers and technicians. Skilled workers and the like are recruited locally." CEO, large oil and gas supplier

Norwegian-based suppliers that have successfully established themselves in foreign oil and gas provinces are unanimous in their opinion that establishment of foreign subsidiaries is paramount to success.

> "The up-and-coming oil and gas provinces, like Brazil, tend to require 'local content', so it is imperative to 'set up shop' in those countries. But this is also economically sound, as locals are cheaper than expatriates. We didn't make money in Africa before we were at 80 percent local personnel." FMC Technologies (presentation at the Offshore Strategy Conference, 2011)

> "Success on the Brazilian market requires the establishment of a Brazilian subsidiary, preferably with a Brazilian CEO." Maritimt Forum (presentation at the Offshore Strategy Conference, 2011)

As is discussed in more detail in a section 6, the competence in the Norwegian oil and gas cluster has been developed from confronting and solving practical challenges on the Norwegian continental shelf. A decrease in activity on the NCS may, therefore, have a

dramatic effect on the future accumulation of knowledge and, thus, on the future internationalization of the Norwegian oil and gas industry.

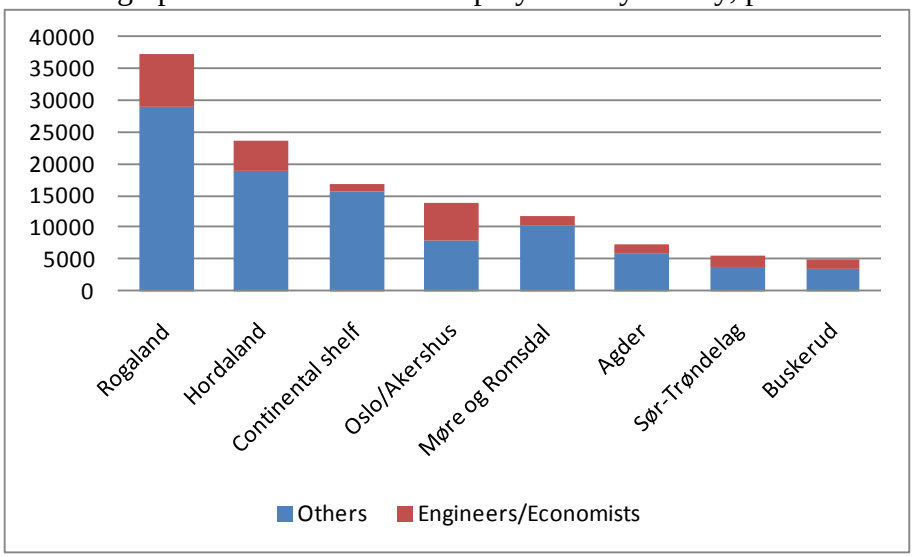
> "There is a fundamental 'disconnect' in the current Norwegian debate, namely that we will be able to live off of knowledge alone after the end of the oil 'adventure'. But knowledge does not arise out of nothing. It tends to be based on experience from very specific activities – in many cases, the handling of natural resources." Senior executive, major global operator

3.5 Geographical distribution of employment

One problem associated with the use of company employment data is that employees are counted as belonging to the county in which the company is headquartered. By using employment data from Statistics Norway, we may assign employees to either the county in which they work (place of work) or the county in which they live (place of residence) regardless of where the companies are headquartered. In addition to data on total employment, the employment register provides data on employee competences. In this respect, we focus on the relative amounts of the two kinds of higher-educated personnel that are most important for technological and business development in this industry: engineers[22]and employees with a business administration or economics education economists (we refer to the latter group as economists or business administration employees interchangeably).

Figure 3-10 depicts oil and gas-related employment in 2008 in the counties (including the continental shelf) where the highest oil and gas industry is responsible for the highest share of employment.

Figure 3-10: Geographical distribution of employment by county, place of work (2008)



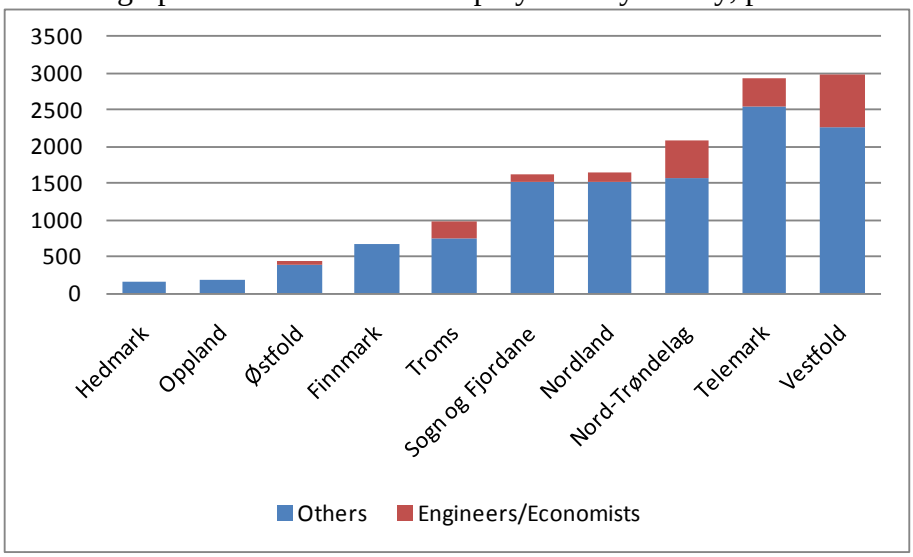
Sources: Statistics Norway – Employment Register, IRIS/BI

As shown in Figure 3-10, Rogaland is the county with the highest share of employment in the Norwegian oil and gas industry. Rogaland has 37,300 employees in this industry, which is nearly one-third of all oil and gas-related employment in Norway. However, Hordaland is a close second with 23,500 employees. Together, Rogaland and Hordaland represent almost

[22] Personnel with degrees in science are also included.

half of all employment in the industry.[23] The third-largest county in this respect is the Continental shelf (i.e., employees with a primary place of work on a vessel or on an offshore installation) with almost 17,000 employees. Oslo and Akershus combined rank fifth in total, but rank first in terms of the penetration of engineers and economists. Sør-Trøndelag and Buskerud also show relatively high penetrations of engineers and economists.

Figure 3-11: Geographical distribution of employment by county, place of work (2008)



Sources: Statistics Norway – Employment Register, IRIS/BI

Figure 3-11 shows that the nine counties with the least oil and gas related employment include the inland counties of Hedmark and Oppland, and the three counties constituting northern Norway (Finnmark, Troms and Nordland). Of these nine counties, Troms and Nord-Trøndelag show relatively high shares of engineers and economists. Taken together, these nine counties have total oil and gas employment of almost 14,000.

Geographical distribution of penetration of engineers/science and business administration employees

The relative share of engineers and economists in each county reflects the relative specialization of those counties. This may be a vital factor in a county's ability to adapt to the changing activity level on the NCS. The more labor-intensive-specialized regions are likely to experience further growth when the focus shifts to MMO. This is likely to be followed by a sharp decline. The engineering-based counties are likely to face a period of adaptation, from which some firms may emerge as global suppliers and others may cease operations.

To gain a sense of relative regional strengths and weaknesses, it is instructive to map oil and gas-related employment by county. Total regional employment provides an indication of the industry's relative importance. To account for differences in activities, it is important to distinguish between different kinds of employment.

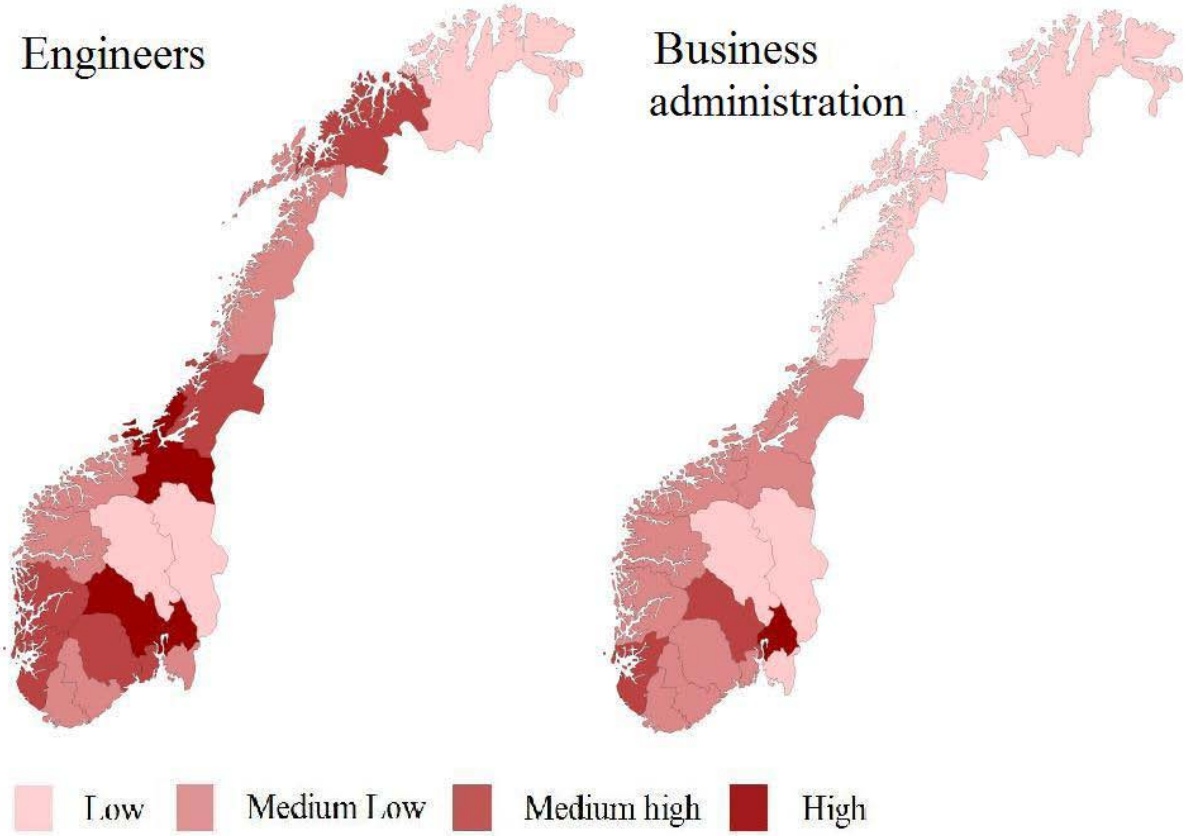
The maps provided in Figure 3-12 indicate the proportion of employees with an engineering or business administration education by region. We first compute the industry average and then divide the distribution into four levels: low (more than one standard deviation below the

[23] Given the total private sector employment of 173,000 in Hordaland and 169,000 in Rogaland, this implies that the oil and gas industry's share of total private sector employment in these two counties is 14 percent and 22 percent, respectively.

mean), low-medium (one standard deviation or less below the mean), medium-high (one standard deviation or less above the mean) and high (more than one standard deviation above the mean).

On the basis of this analysis, we find that the most engineer-heavy regions are Oslo/Akershus, Buskerud and Sør-Trøndelag (marked in the darkest red on the map). The typical oil counties of Hordaland and Rogaland on the west coast of Norway are slightly less engineer driven. This latter group also includes Nord-Trøndelag, Troms, Telemark and Vestfold.

Figure 3-12: Regional specialization – relative intensities of employees educated in engineering or business administration (2008)



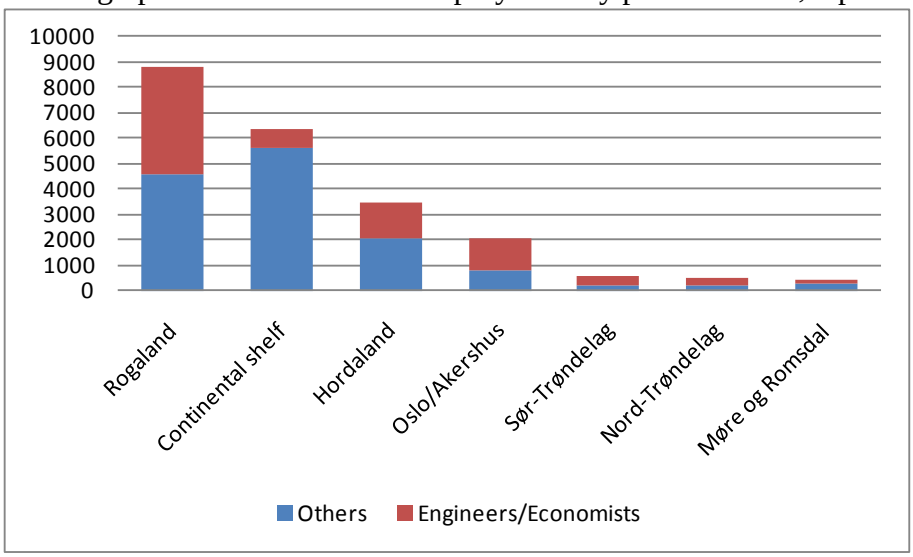
Sources: Statistics Norway – Employment Register, IRIS/BI

The results of an examination of the distribution of business and economics employees by region are as expected. The top region is Oslo/Akershus, as the headquarters of many companies filling support functions are located in this region. The second-strongest regions are Rogaland and Buskerud. The third-largest group encompasses the nine remaining counties in the southern part of Norway, with the exception of the inland counties of Oppland and Hedmark (Figure 3-12).

Geographical distribution of employment by sector

Regional employment varies by educational background and sector. The distribution of the oil industry is not homogenous and, in this regard, it highlights the clustering of activities in specific regions and the important role that districts play in this industry.

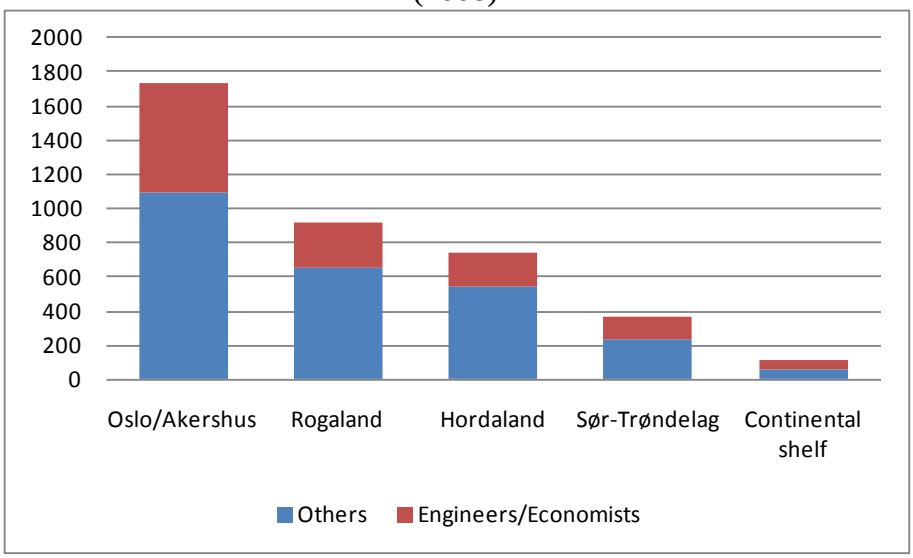
Figure 3-13: Geographical distribution of employment by place of work, Operators (2008)



Sources: Statistics Norway – Employment Register, IRIS/BI

With almost 9,000 employees in 2008 (Figure 3-13), the highest share of employment of Operators is in Rogaland, the county in which the most headquarters of both national and international Operators are located. The second-highest concentration of Operators is on the Continental Shelf (6,400). Hordaland has the second-highest concentration on the mainland (3,500). Oslo/Akershus has only 2,000 employees working for Operators but two-thirds of these are engineers or economists.

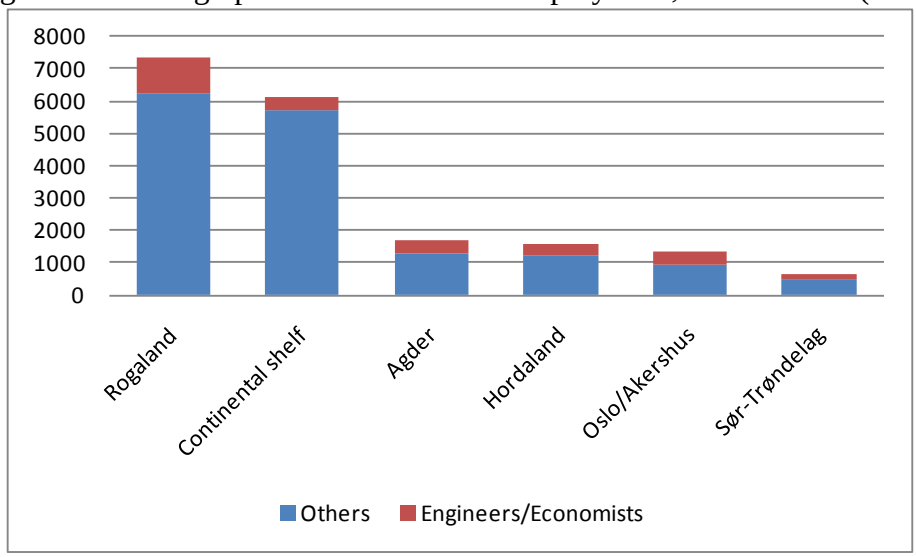
Figure 3-14: Geographical distribution of employment by place of work, Geo & Seismics (2008)



Sources: Statistics Norway – Employment Register, IRIS/BI

As Figure 3-14 illustrates, employment in Geo & Seismics is dominated by Oslo/Akershus (PGS, Fugro, etc.) both in terms of the total, and in terms of the share of engineers and economists. Hordaland and Rogaland combined have higher employment in total but their share of engineers and economists is lower than in Oslo/Akershus. Sør-Trøndelag comes in fourth with a tiny concentration in total but with a high penetration of engineers/economists.

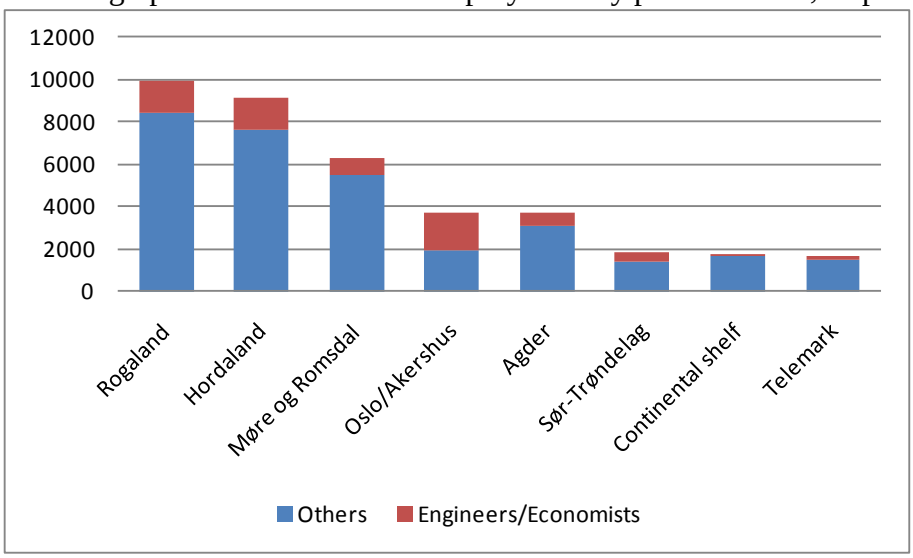
Figure 3-15: Geographical distribution of employment, Drill & Well (2008)



Sources: Statistics Norway – Employment Register, IRIS/BI

With 7,300 employees in Drill & Well (Figure 3-15), Rogaland, home to the major oil service firms (Schlumberger, Halliburton, BakerHughes, Seawell, etc.), ranks first among the mainland counties. There is also considerable activity in Agder (the NODE cluster in drilling and topside equipment[24]) and Hordaland.

Figure 3-16: Geographical distribution of employment by place of work, Topside (2008)



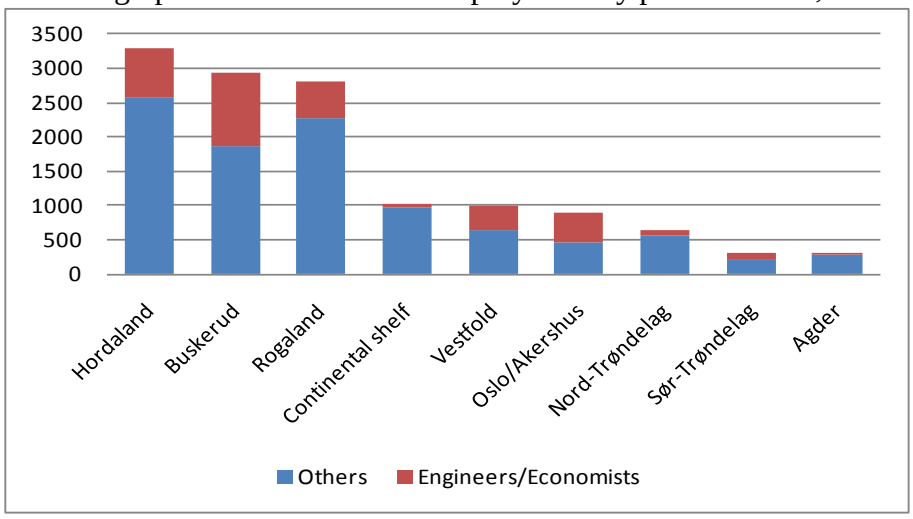
Sources: Statistics Norway – Employment Register, IRIS/BI

Employment in Topside is mainly located in Rogaland (10,000 employees) and Hordaland (9,100 employees) (Figure 3-16). The third-largest concentration is found in Møre og Romsdal with just above 6,000 employees connected to shipyards. Oslo/Akershus has a concentration of almost 4,000 employees, which is more engineering-based than the concentrations along the western coast. There are also relatively high concentrations in Sør-

[24] The total employment in the NODE cluster is found by combining the employment for Agder in Drill & Well and in Topside.

Trøndelag (Aker Verdal), on the Continental Shelf (Topside includes maintenance offshore) and in Telemark (Grenland Group).

Figure 3-17: Geographical distribution of employment by place of work, Subsea (2008)

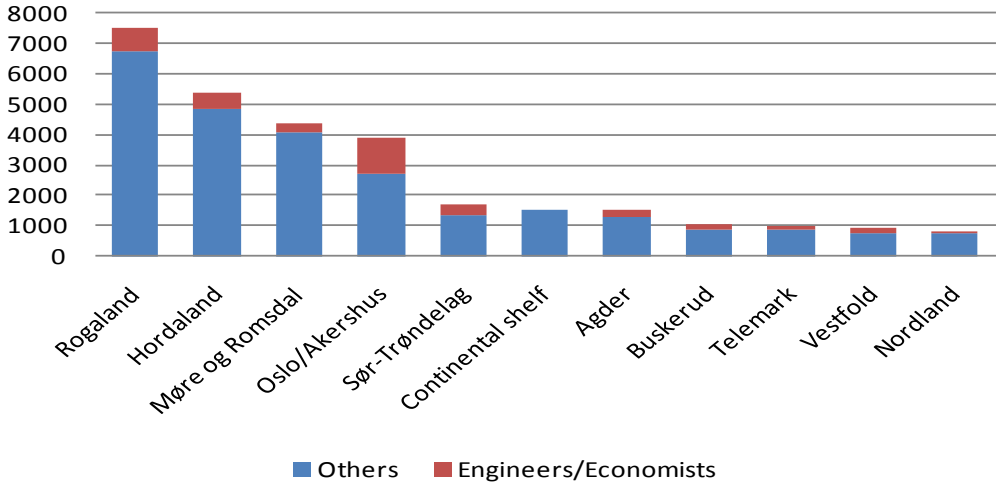


Sources: Statistics Norway – Employment Register, IRIS/BI

For a long time, the eastern part of Norway, Buskerud (the home of FMC Technologies), parts of Vestfold and Oslo/Akershus (the home of Aker Subsea) have been known as 'Subsea Valley'. Figure 3-17 supports this view in terms of the reliance on engineers and economists: Buskerud, Vestfold and Oslo/Akershus together employ 1,875 engineers and economists. However, in terms of all subsea personnel, the country's largest subsea cluster is located in Hordaland, which is home to NCE Subsea with 3,300 subsea-related employees.[25] Rogaland comes in third with 2,800 employees (Subsea 7, Island Offshore Subsea, etc.). When compared to the subsea activities in Oslo/Akershus/Buskerud, the subsea activities in Rogaland and Hordaland are directed more towards operations and construction, although Rogaland/Hordaland is also home to technology providers like Framo Engineering, Roxar and MPM.

[25] NCE Subsea in Bergen reports subsea-related employment of 4,600. Figure 3-17, however, only includes employment in companies predominantly associated with the Subsea sector.

Figure 3-18: Geographical distribution of employment by place of work, Operations Support (2008)



Sources: Statistics Norway – Employment Register, IRIS/BI

Employment in Operations Support is concentrated in the western counties of Rogaland, Hordaland and Møre og Romsdal. Oslo/Akershus ranks fourth but it has a much higher reliance on engineers and economists (Figure 3-18). The figure summarizes the findings thus far for the counties with the major part of oil and gas-related employment (including the Continental Shelf). The table shows employment divided into engineers and economists, and other professions in the six sectors of the industry. The regional distribution of employment by place of work is rounded to the nearest hundred and '-' indicates a number below 50. 16 regional concentrations – regional clusters – are distinguished in the following way: a regional cluster is identified in a sector if one county or a number of geographically close counties hold a significant amount of total employment within the sector. Regional clusters in which the share of engineers/economists exceeds 30 percent are marked with a red, rounded rectangle and with the number of economists/engineers in bold. Regional clusters with a share of engineers/economists below 30 percent are marked with a blue, rounded rectangle. Clusters with an absolute amount of engineers/economists above 1,000 are marked with a green, rounded rectangle and with the number of economists/engineers in bold

Oslo/Akershus has significant engineering/economist penetrations in all sectors with the exception of Drill & Well. The engineering/economist-intensive Subsea cluster of Oslo/Akershus extends into Buskerud (the Kongsberg region). Agder counties in southern Norway have significant concentrations in Drill & Well and Topside (the NODE cluster) with a relatively low share of engineers/economists. Rogaland and Hordaland belong to concentrations in all six sectors. The regional concentration in Operators between Rogaland and Hordaland is the only regional concentration outside of Oslo/Akershus with a share of engineers/economists above 40 percent.

Hordaland is home to NCE Subsea and, although the relative intensity of subsea engineers and economists is higher in Oslo/Akershus/Kongsberg, the total number of Subsea employees is higher in Hordaland and Rogaland combined. Rogaland has the largest Drill & Well cluster in the country. Even though the relative share of engineers/economists is low (15 percent), the total number (1,100) is significant. Hordaland also has a concentration in Drill & Well but this is considerably smaller than the concentration observed in Rogaland. The regional concentration in Topside in Rogaland and Hordaland also has a relatively low share of

engineers/economists (15 and 16 percent, respectively), but a significant total number of engineers/economists (3,000). Both counties also have strong maritime clusters in Operations Support. Møre og Romsdal has a regional cluster in the maritime parts of Drill & Well, Topside, Subsea and Operations Support. Sør-Trøndelag has two smaller engineering/economist-intensive clusters, one in Operators (the county serves as the location of Statoil's research facility) and Geo & Seismics, and one in Operations Support.

Table 3-3: Regional distribution of employment by place of work (2008) rounded to the nearest hundred ('-' indicates employment below 50)

		Operators	Geo & Seismics	Drill & Well	Topside	Subsea	Operation Support	Total
Oslo/ Akershus	**Other employees**	800	1 100	900	1 900	500	2 700	**7 900**
	Engineers/ Economists	**1 200**	**600**	400	**1 800**	**400**	**1 200**	**5 800**
Buskerud	**Other employees**	0	0	300	400	1 900	900	**3 400**
	Engineers/ Economists	0	0	100	100	**1 100**	200	**1 400**
Agder	**Other employees**	0	0	1 300	3 000	300	1 300	**5 900**
	Engineers/ Economists	0	0	400	700	-	200	**1 300**
Rogaland	**Other employees**	4 600	700	6 200	8 400	2 300	6 700	**28 900**
	Engineers/ Economists	**4 200**	300	**1 100**	**1 500**	500	800	**8 400**
Horda-land	**Other employees**	2 100	500	1 200	7 600	2 600	4 900	**18 900**
	Engineers/ Economists	**1 400**	200	400	**1 500**	700	500	**4 600**
Møre og Romsdal	**Other employees**	300	100	300	5 500	200	4 000	**10 300**
	Engineers/ Economists	100	0	100	800	-	300	**1 300**
Sør-Trønde-lag	**Other employees**	200	200	500	1 400	200	1 300	**3 900**
	Engineers/ Economists	**300**	**100**	100	400	100	**400**	**1 500**
Conti-nental shelf	**Other employees**	5 600	100	5 700	1 700	1 000	1 500	**15 600**
	Engineers/ Economists	800	100	400	-	100	0	**1 300**
Other counties	**Other employees**	400	-	300	4 500	1 400	4 900	**11 600**
	Engineers/ Economists	600	-	-	600	500	500	**2 200**
Norway (all counties)	**Other employees**	**14 000**	**2 700**	**16 700**	**34 400**	**10 400**	**28 200**	**106 400**
	Engineers/ Economists	**8 600**	**1 300**	**3 000**	**7 400**	**3 400**	**4 100**	**27 800**
Norway	**Total**	**22 600**	**4 000**	**19 700**	**41 800**	**13 800**	**32 300**	**134 200**

Sources: Statistics Norway – Employment Register, IRIS/BI

3.6 Cluster attractiveness: Conclusions

The Norwegian oil and gas industry is viewed as having a very high level of competence compared to other oil and gas hubs (Houston and the UK). Norwegian-based firms cover all technical parts of the value chain and Norway has become the global hub for many of these activities. There is a healthy distribution of companies of different sizes from startups to large companies. The last ten years have seen an improvement in terms of both access to capital and quality of financial services provided. However, for the larger companies, there is still a wide spread dependency on international finance institutions.

All sectors in the industry report high earnings for personnel (measured in terms of personnel costs per employee) and for capital (measured in terms of operating margins). Personnel costs are the highest in the Geo & Seismics and Drill & Well sectors, and the lowest in Operations Support and Topside. Profit margins are the highest among Operators, most probably as a result of the petroleum rent's role in capital yield. Among suppliers, profit margins are highest in Geo & Seismics, Drill & Well and Operations Support, and lowest in Topside.

Value creation per employee[26] ranges from NOK 1.2 million for suppliers to NOK 7.1 million for Operators. In comparison, value creation per employee in the Tourism industry is NOK 0.4 million, while it is NOK 1.4 million in the Maritime sector, which includes parts of the oil and gas industry (Knowledge-Based Norway projects of Tourism (2010) and Maritime (2011).

The supplier industry has successfully managed internationalization. It is estimated that 30 percent of sales in Norway are exported. Exports from oil and gas suppliers, then, represent approximately 15 percent of total Norwegian exports when direct sales of oil and gas are excluded. In addition to the export value, there is also capital income from repatriated profits from foreign subsidiaries.

Two factors force Norwegian-based companies to establish local subsidiaries when they want to conduct business in promising new offshore provinces, such as Brazil or West Africa. The first is national demand for 'local content', i.e., the same forces that helped shape the Norwegian-based supplier industry. The second is an economic factor – foreign operations would not be competitive if based solely on Norwegian expatriates and Norwegian-made materials.

A division of the industry into regional subclusters reveals significant regional variations in terms of total employment and in the use of personnel with higher education (engineers and economists). Of the mainland counties, the bulk of employment (just below 50% of the total) is located in Rogaland and Hordaland, followed by Oslo/Akershus, Møre og Romsdal, Agder counties, Sør-Trøndelag, and Buskerud. The subclusters in Oslo/Akershus (all sectors excluding Drill & Well) and in Buskerud (Subsea) have significantly higher shares of engineers/economists than other regional clusters. However, the absolute numbers of engineers/economists in the Drill & Well cluster in Rogaland and in the Topside cluster in Rogaland/Hordaland are significant.

[26] An estimate of the petroleum rent has been deducted from the value creation figure for Operators.

4 Education Attractiveness

The ability of an industry to successfully compete in its relevant market is increasingly dependent on investments in human capital. Clusters are specialists in translating generic education into productive use. While educational programs in various disciplines are found around the globe, we generally find only a few clusters for each discipline and these are located in just a few countries. The distribution of commercial activity based on knowledge of a specific discipline or, even more so, when the combination of knowledge of a number of disciplines is required is spiky. In other words, it is not uniformly distributed across countries or regions.

Clusters can only excel in productively channeling knowledge if the human capital existing in educational institutions has the necessary basic knowledge and if that knowledge is increasing. Investments in human capital are first made by educational institutions outside the scope of control of industrial actors. Such investments enable the creation of industries. If they are lacking, they contribute to the disappearance of industrial activities (for example, the required knowledge about constructing hydropower stations no longer resides within the human capital of the younger generation of Norwegians as a result of political factors, educational factors and a substantial reduction in the activity level). All else equal, if an industry is to be attractive over an extended period of time, it must be able to attract the best human capital into educational programs that provide the prerequisite knowledge upon which firms can build further. In this section, therefore, we focus on the investments made by educational institutions, while we focus on competence development programs initiated by the firms themselves in section 9.

Human resources generally receive advanced, subject-specific education through public education systems. As the OECD comments, "…almost every aspect of R&D and innovation requires the input of skilled people" (OECD 2010: 41). On a country level, Norway as a whole has performed worse than the vast majority of OECD countries with regards to education. The proportion of graduates with science and engineering degrees increased slightly from 1998 to 2007. Norway educated approximately 7.5 percent of its graduates in engineering and an equivalent percentage in science, which places Norway in sixth-last place among the OECD countries (OECD 2010). Furthermore, there are even greater grounds for concern when the shares of degrees awarded to women are examined. With only 28 percent of such degrees awarded to women, Norway exhibits lower levels of gender equality than other OECD countries, including the traditionally male-dominated societies of Italy (38 percent) and Spain (37 percent), and lower levels than in other Scandinavian countries (Finland 29 percent; Sweden 34 percent; Denmark 34 percent). Therefore, it is pertinent to examine the extent to which Norway educates future generations in subjects pertaining to the oil and gas industry.

4.1 Educational capacity in oil and gas-related subjects

When oil and gas exploration began in Norway, there was no indigenous workforce with the relevant qualifications, so most senior positions were held by foreigners with the majority of employees coming from the US. With the development of the Frigg field, a significant number of French citizens also came to Norway. As the costs of using foreign personnel rose, Norwegian personnel came to be increasingly used as 'roustabouts' – they were placed in the most junior positions offshore.

As the Norwegian labor market was at capacity, the Norwegian government did not take any initiatives to boost national educational capacity in oil and gas-related subjects (Ryggvik 1997). Despite the lack of state support, however, several universities and community colleges established courses in oil and gas-related subjects. The educational programs in geology at the universities of Oslo and Bergen were strengthened; the program in shipping and mining at the Norwegian Institute of Technology (NTH) was adapted to the needs of the petroleum industry; and Rogaland Community College (now the University of Stavanger) started training petroleum engineers (Hanisch and Nerheim 1993). Despite these efforts, the share of foreign workers in the petroleum workforce steadily increased to 20 percent for the country as a whole and to more than 30 percent in the main petroleum county, Rogaland (Ryggvik 1997). However, in 1978, the Norwegian government informed foreign petroleum firms that the use of Norwegian personnel would be one evaluation criterion used in assessing applications for new licenses on the NCS (Ryggvik 1997).

An attractive education program should lead to increasing interest in the program in absolute and relative terms. Absolute terms concern the availability of qualified personnel in the future, while relative terms concern the relative attractiveness of the subject to the general student population. All else equal, lower figures in relative terms will lead to the relevant industry representing a lower share of GDP in the future because a growing number of graduates will find employment in firms engaged in other activities.

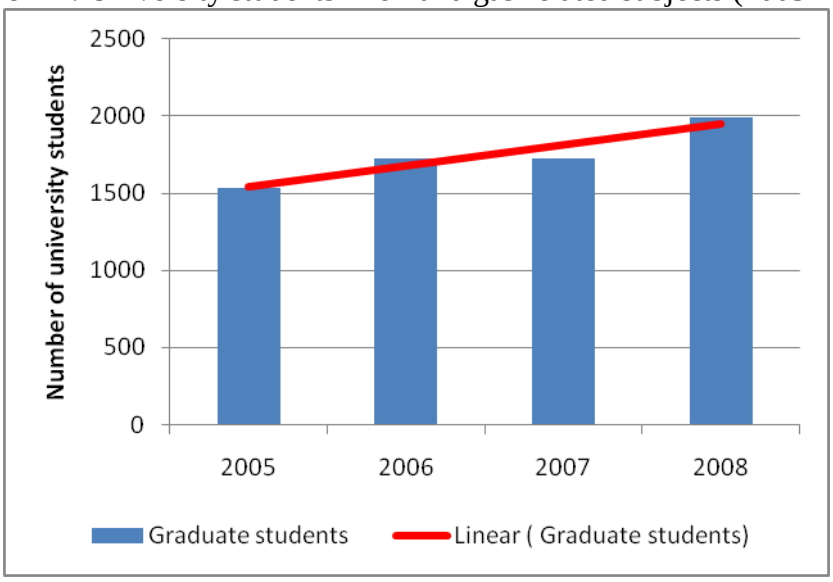
In this study, 'education attractiveness' is operationalized in the following manner:

- Level and growth of university students studying in oil and gas-related fields,
- Share of university students studying oil and gas-related fields,
- Level and growth of PhD students studying in oil and gas-related fields, and
- Share of PhD students studying in oil and gas-related fields.

A distinction is made among the Bachelor, Master and PhD levels. University students are therefore specifically categorized as Bachelor, Master or PhD students in oil and gas-related subject areas. To account for the lack of data on PhD students before 2002 and the impact of the Step I implementation of the Amendments to the University Acts in 2002[27], which followed the Bologna process on higher education, the analysis is conducted using annual figures for the period from 2005 to 2008.

[27] The amendments in pursuance of the EU harmonization of educational programs to Bachelor, Master and PhD.

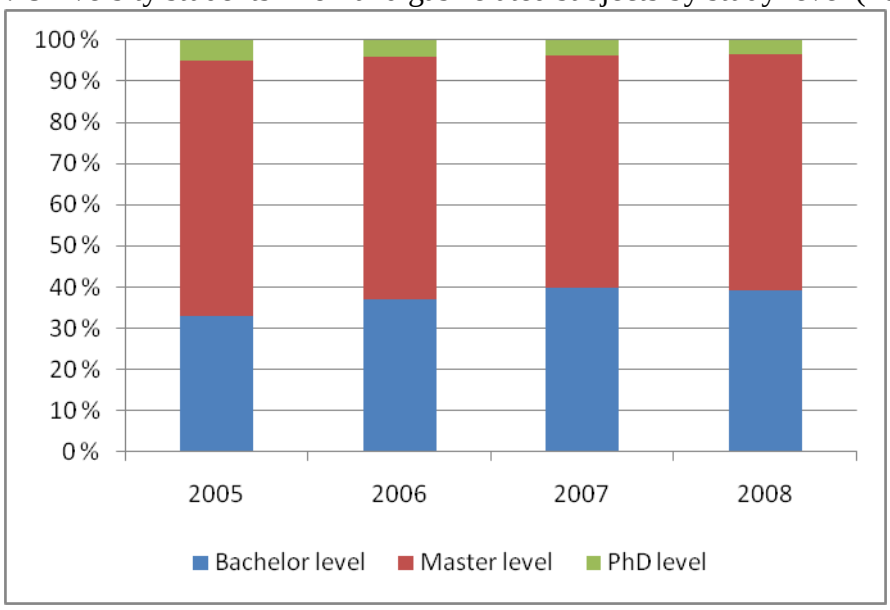
Figure 4-1: University students in oil and gas-related subjects (2005-2008)



Sources: NSD, IRIS/BI

As Figure 4-1 shows, the number of university students enrolled in oil and gas-related subjects has increased every year with the exception of 2007. The annual growth rate in the number of university students studying oil and gas-related subjects averages about 8 percent per year. The two largest dedicated educational programs are Master studies in petroleum technology and Bachelor studies in engineering with a major in petroleum technology. Growth rates in these dedicated study subjects have fluctuated over the years but have been on a declining trend in the past years. However, the general trend is positive in absolute terms when the more generalist engineering education is included.

Figure 4-2: University students in oil and gas-related subjects by study level (2005-2008)

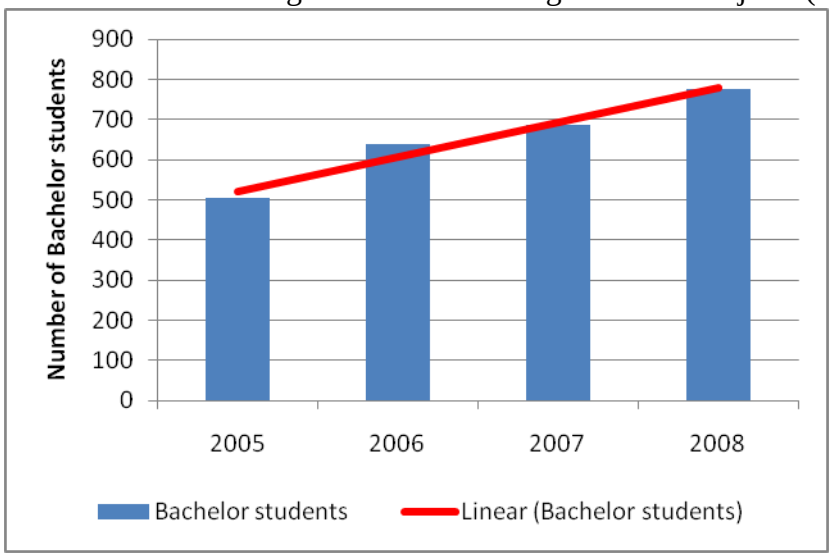


Sources: NSD, IRIS/BI

Figure 4-2 illustrates the distribution of higher education over time. The share of Bachelor students is increasing, while the shares of Master and PhD level students is decreasing. In 2008, 39 percent of the students in subjects related to the industry were enrolled in Bachelor studies, 58 percent of the students were engaged in Master-level studies and the remaining 3

percent were enrolled in PhD programs. The growth and attractiveness of oil and gas-related subject areas are further highlighted when we examine Bachelor, Master and PhD programs individually.

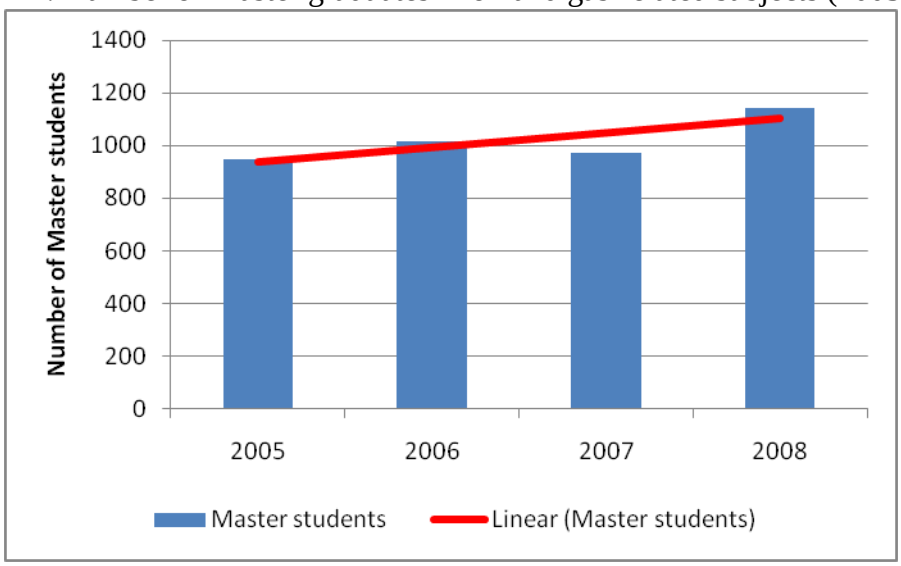
Figure 4-3: Number of Bachelor graduates in oil and gas-related subjects (2005-2008)



Sources: NSD, IRIS/BI

The number of Bachelor students in subject areas directly related to oil and gas has been increasing every year.[28] While a reclassification of degrees resulted in high annual growth rates from 2002 to 2004, the number of Bachelor students has recently grown at an average annual growth rate of just below 15 percent (Figure 4-3). This development is significantly above the average growth rate for all Bachelor-level students of 4 percent during the same period.

Figure 4-4: Number of Master graduates in oil and gas-related subjects (2005-2008)



Sources: NSD, IRIS/BI

[28] Only dedicated Bachelor studies are included.

Figure 4-4 shows that there is a positive linear trend in the number of Master students in subject areas related to the oil and gas industry. Average annual growth amounts to 6 percent (2005-2008). This trend can be viewed as positive when compared to the 0.4 percent average decline in the number of Master students in all other subject areas during the same period. Moreover, the number of Master students in oil and gas related fields increased by more than 17 percent in 2008, which may be attributable to unfavorable employment market conditions during the peak of the financial crisis.

Case: Specialized Education Programs

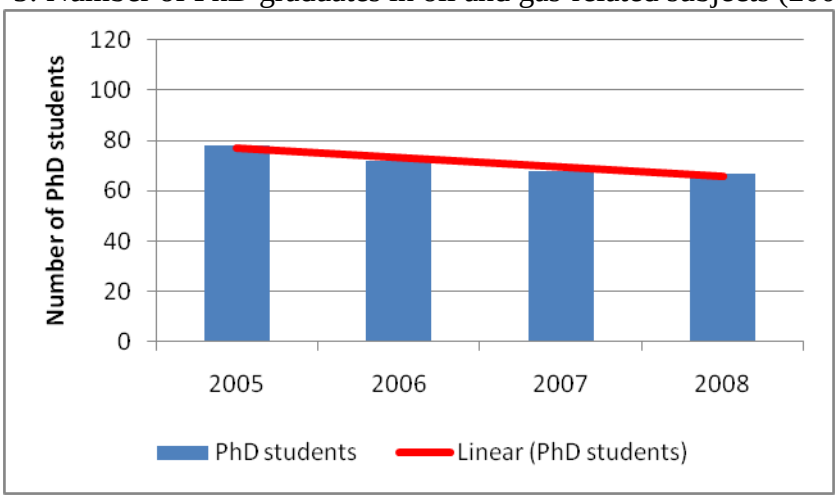
In order to promote competence within the Norwegian Center of Excellence known as NODE (Norwegian Offshore & Drilling Engineering), the NODE Kompetansesenter (Competence Center) was established in 2009. Given the growing demand for further education and training, the Competence Center aims to provide firms with offers for further education tailored to the specific needs of the industry. Two initiatives that address the medium and long-term needs of the industry are particularly notable.

First, in order to strengthen engineering competencies, the Competence Center developed Bachelor and Master-level programs in mechatronics in cooperation with the University of Agder. In this regard, the Competence Center cooperated closely with the University of Agder to provide courses tailored specifically to the needs of the industry. In 2010, a Master level course in logistics and project management, directed towards oil and gas suppliers, was launched.

Second, the Center develops managerial competences and change management skills through its cooperation with BI Norwegian School of Management, where industry employees can take project-management classes that may be used towards completion of a Bachelor of Management in Project Management. Moreover, a tailor-made, part-time master program, the Master in Innovation and Business Development, is offered as part of the Master of Management program at BI Norwegian School of Management.

In addition to these initiatives, the Center offers professional language courses for mechatronics engineers and provides financial support to PhD students focusing on the subject area.

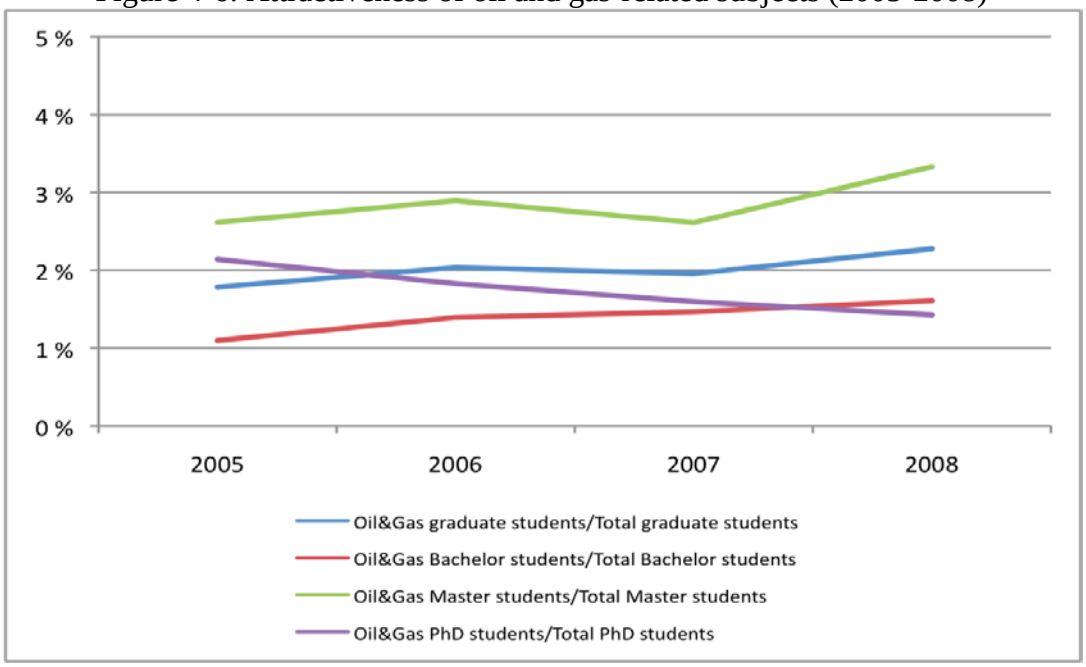
Figure 4-5: Number of PhD graduates in oil and gas-related subjects (2005-2008)



Sources: NSD, IRIS/BI

A negative trend is apparent among the "upper crust" of university studies. As the negative slope of the trend line in Figure 4-5 indicates, the number of PhD students in industry-related subject areas is declining. The average rate of decline amounted to 5 percent per annum between 2005 and 2008. This trend is of particular concern in light of the average annual growth rate in the total number of PhD students in Norway of 11 percent (2005-2008). This lack of investment in advanced knowledge in oil and gas-related subject areas may be attributed to a number of factors. If we examine the two main sources of funds for doctoral programs, the state and large firms with vested interests, both indicate expected decreasing returns on investments in advanced subject-specific knowledge. We return to this point in section 6.

Figure 4-6: Attractiveness of oil and gas-related subjects (2005-2008)



Sources: NSD, IRIS/BI

Figure 4-6 depicts the percent of students of oil and gas related subjects out of the population of students by educational level. Comparing the totality of all subject areas in Norway, the proportion of Bachelor and Master students engaged in studies of oil and gas-related subject areas has been increasing faster than the general growth rate. At the same time, the clear decline in doctoral graduates (from 2.4 percent in 2005 to 1.4 percent in 2008) evident in Figure 4-6 is a source of concern in terms of future investments in petroleum-related advanced technologies.

Case Specialized Education Programs

In order to promote competence within the Norwegian Center of Excellence: NODE (Norwegian Center of Excellence: Norwegian Offshore & Drilling Engineering), NODE Kompetansesenter (Competence Center) was established in 2009. Being aware of the growing demand for further education and training, the Competence Center aims at providing firms with offers for further education tailored to the specific needs of the industry. Two initiatives that address the medium and long term needs of the industry are especially worthy of consideration.

First, in order to strengthen engineering competencies the Competence Center, in cooperation with the University of Agder, developed Bachelor and Master level programs in mechatronics. The Competence Center cooperated tightly with the University of Agder to provide courses tailored specifically to the needs of the industry. In 2010, a Master level course in Logistics and Project Management directed towards oil and gas suppliers was launched.

Second, managerial competences and change management skills are developed through cooperation with BI Norwegian School of Management where employees can take project management classes that may be extended towards a Bachelor of Management in Project Management. Moreover, a tailor-made part-time master program, the Master in Innovation and Business Development, can be taken as part of the Master of Management program at BI Norwegian School of Management. In addition to these initiatives, the center offers professional language courses for mechatronics engineers and provides financial support to invest in PhD students in the subject area.

4.2 Educational attractiveness: Conclusions

In summary, educational programs that are related to the oil and gas industry have been growing in popularity in absolute and relative terms on both the Bachelor and Master levels. However, programs dedicated to the petroleum industry have been losing students in recent years. This situation reflects the continuing interest in engineering and related topics but with an increasing focus on renewable energy and other technologies that are perceived to be environmentally friendly. For doctoral studies, both the absolute number of students and the relative proportion of students are declining. As doctoral studies have the longest time horizon, investment in such studies indicates that there are opportunities for either advanced employment or future academic life within this specific area. Taking this into consideration, the declining attractiveness of doctoral programs in the relevant areas might constitute an early signal that the opportunities for advanced R&D-based value addition in the oil and gas industry are declining.

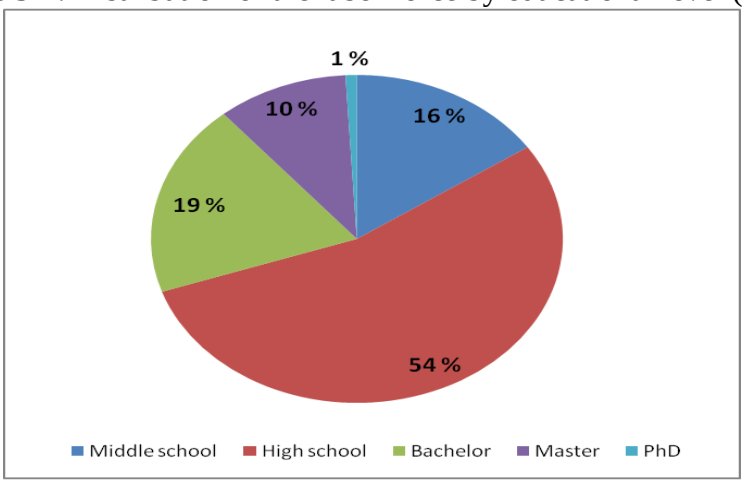
5 Talent attractiveness

Educational institutions produce a unique resource: knowledge workers. Industries and firms compete in labor markets to attract the most talented knowledge workers. To the extent that an industry can attract talented individuals, it is better positioned than an industry that cannot. For an industry to be competitive over a long period of time, it must be able to attract highly competent human capital before committing resources to invest in new technologies and competence development. In this section, we focus on the degree to which the oil and gas industry is successful in recruiting and retaining highly developed human capital. In section 9, we focus on competence development programs initiated by the firms themselves.

5.1 Education level

The global oil and gas industry is often seen as 'low tech' and the industry is generally not viewed as a 'knowledge-based industry'. A number of the executives interviewed for this project explain that this view might be partly due to the fact that oil and gas workers tend to be poorly educated in many oil and gas regions. In contrast, the Norwegian oil and gas industry has focused on the need for the vast majority of workers to hold at least a certificate of apprenticeship.

Figure 5-1: Distribution of the labor force by educational level (2008)



Sources: Statistics Norway, IRIS/BI

Figure 5-1 displays the educational breakdown of the labor force employed in the Norwegian oil and gas industry in 2008. The division is similar to the entire privately employed workforce in all industries in Norway. Therefore, on aggregate, the oil and gas industry does not attract a disproportionate percentage of advanced human capital relative to the available workforce.

> "I would say that 50 percent of our activity is knowledge intensive. By this, I mean that the workers have a level of education beyond the certificate of apprenticeship, be it as a technician or engineer. Our workers do not necessarily have to be civil engineers and definitely not PhDs. The majority of our civil engineers work in operations, as our goal is to use knowledge to optimize production." CEO, large oil and gas supplier

The number of employees in the oil sector rose from 2000 to 2008. A relatively stable development can be observed through the early years of the new millennium but remarkable

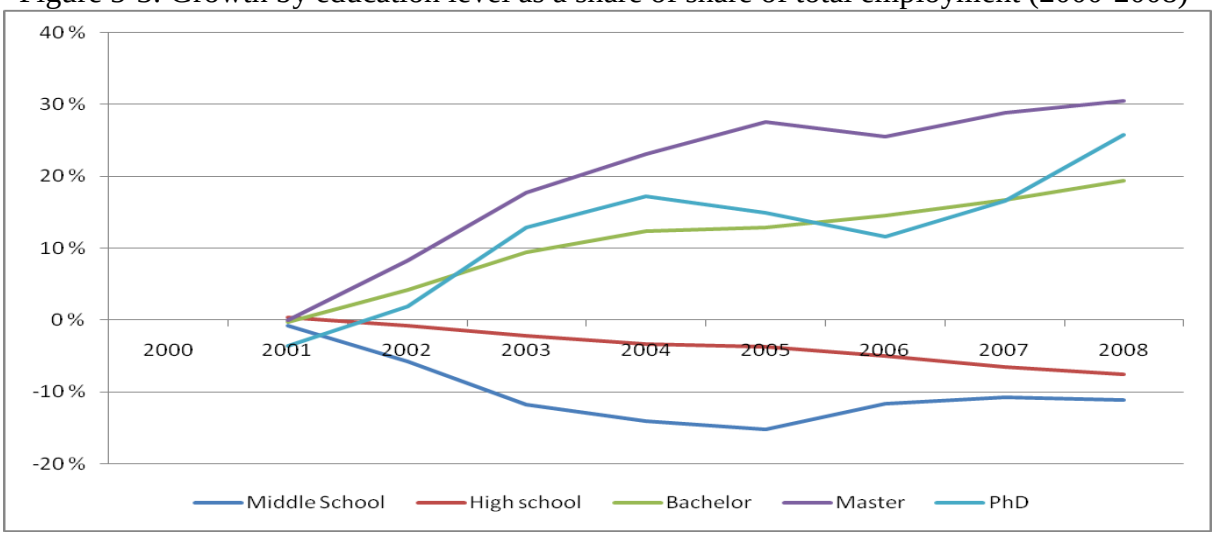
growth was evident from 2004 to 2008. In 2000, employees without a university degree represented 73 percent of the total labor pool in the oil and gas industry. By 2008, the percent of non-university educated in the oil and gas industry had fallen to 67 (85,371 employees). At the same time, the share of university-educated employees had grown to 33 percent of the total labor pool (41,524 workers).

Figure 5-2: Distribution of employees by education level (2000-2008)

Sources: Statistics Norway, IRIS/BI

An examination of the composition of the different educational levels indicates a greater overall demand for employees with higher education (Figure 5-2). There is a clear distinction between the growth rate for employees with a higher education and the growth rate for employees without a university education. Especially noteworthy is the growth of the labor force with a higher education from 2001 until 2004, a period during which the non-university educated labor declined. From 2005 onwards, both university and non-university educated labor experienced high growth rates.

Figure 5-3: Growth by education level as a share of share of total employment (2000-2008)



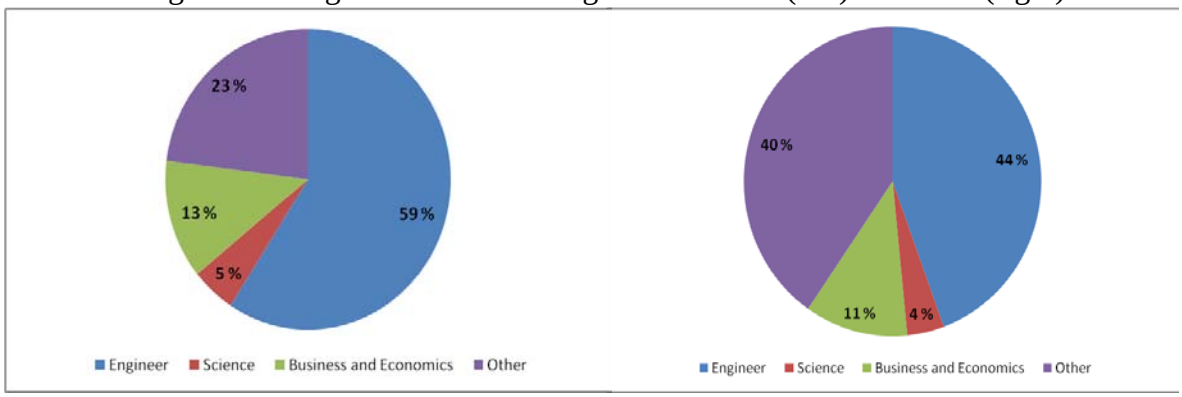
Sources: Statistics Norway, IRIS/BI

After combining the current distribution of the workforce (Figure 5-1) with the growth rates for the various education levels (Figure 5-3), we conclude that the oil and gas industry has increased its professionalization level and has closed the gap in the educational composition of its workforce relative to the rest of the industrial workforce. However, the industry does not attract more specialized labor than is generally available in the population.

5.2 Sources of formal education

The industry is clearly engineering specialized. 44 percent of university-educated employees in the industry in 2008 had engineering degrees. Only 11 percent of the university educated workforce had a business or economics background. Scientists constitute a relatively small share of this industry at a mere 4 percent of the university-educated workforce (Figure 5-4). However, the relative share of engineers is declining. 59 percent of the university educated workforce in 2002 was engineers, while the corresponding figure in 2008 was 44 percent.

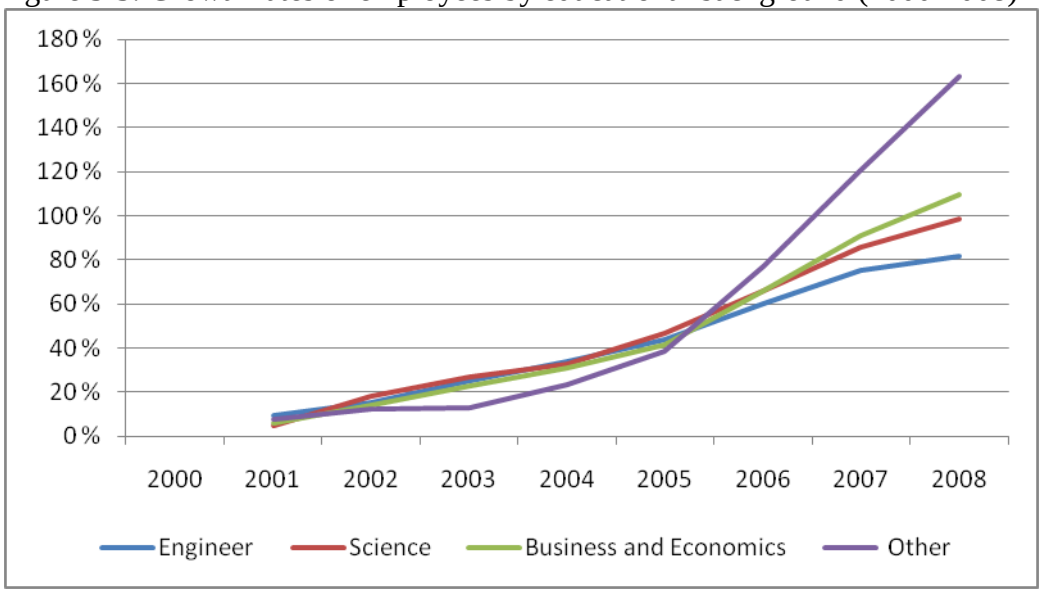
Figure 5-4: Higher education background in 2002 (left) and 2008 (right)



Sources: Statistics Norway, IRIS/BI

The annual growth in employees by educational background was nearly identical from the beginning of the investigated period until 2005 (Figure 5-5). For the rest of the period, higher growth can be observed in the supporting activities. This may indicate a shift in the focus of the Norwegian oil and gas industry, which has been known for its engineering excellence. In this sense, many of the industry's most recognized, value-adding innovations (discussed in the next section) have been based on engineering (e.g., horizontal drilling, subsea systems and floating oil rigs). The increasing employment of talented employees with other educational backgrounds may indicate a lack of qualified personnel, an expectation of decreasing returns on investments in engineering-based projects or the offshoring of engineering activities. We examine the evidence related to these statements in this section.

Figure 5-5: Growth rates of employees by educational background (2000-2008)[29]



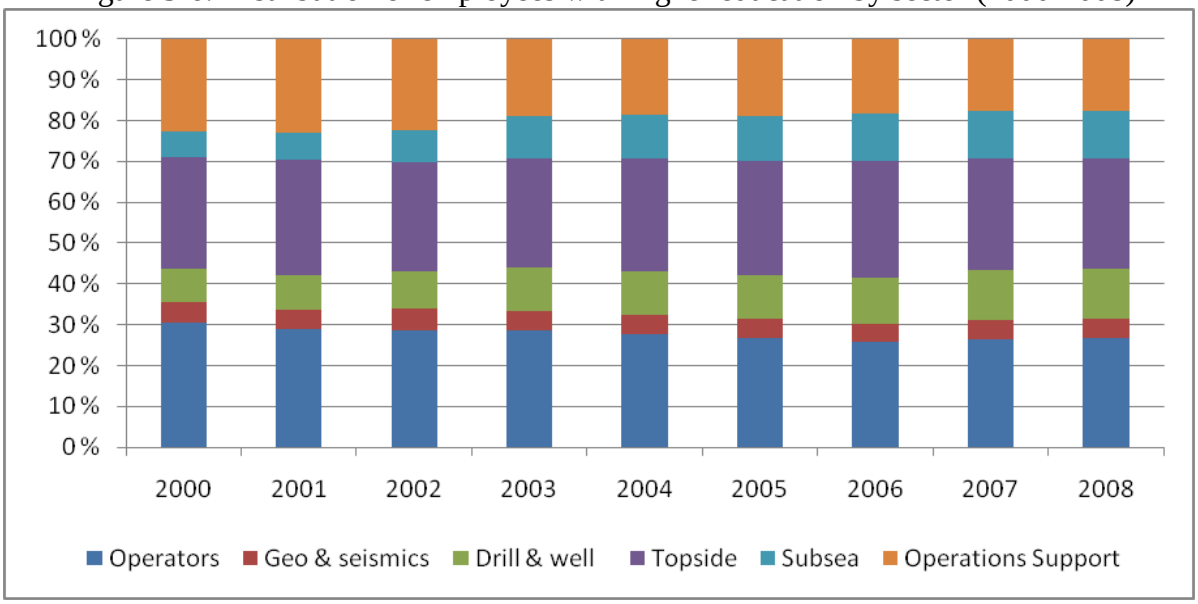
Sources: Statistics Norway, IRIS/BI

In order to examine the origin of this apparent shift, we analyze the attractiveness of each sector separately. Figure 5-6 displays the composition of employees with higher education in the six sectors of the Norwegian oil and gas industry. Operators, Topside and Operations Support are, by far, the largest sectors in the early stages of the investigated period, but there is a sizeable workforce associated with the Geo & Seismics, Drill & Well and Subsea sectors as well.

> "The increased relative importance of personnel with a higher education in social sciences is, to a large extent, explained by the fact that office personnel without higher education (such as secretaries) are being replaced with personnel with higher education." Head of HR, oil and gas supplier

[29] Given the use of a population of oil and gas firms as of December 31, 2008, the figure should be read as presenting the relevant growth rates of employees that had worked for those oil and gas firms during at any point from 2000 to 2008.

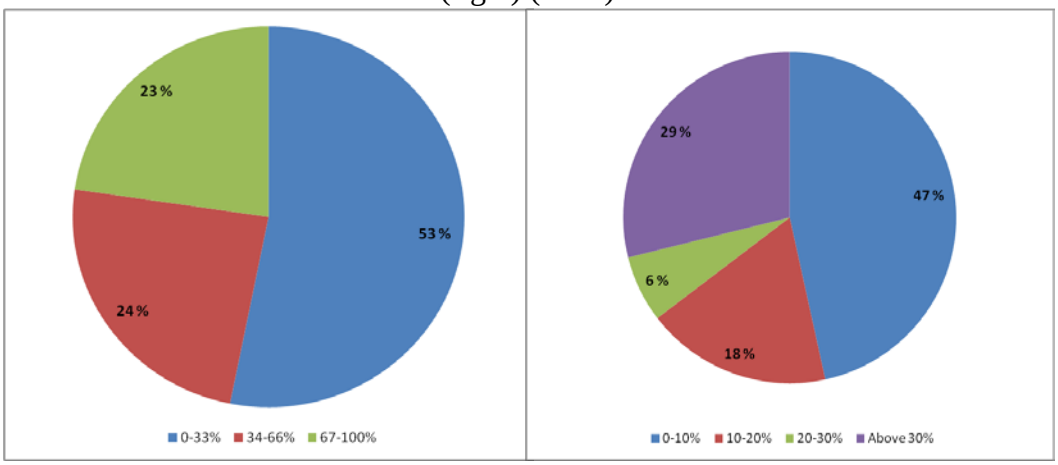
Figure 5-6: Distribution of employees with higher education by sector (2000-2008)



Sources: Statistics Norway, IRIS/BI

Not all value-adding activities require a university education. Operational knowledge is of particular importance in the offshore sector. Figure 5-7 presents the percentage of workers with a certificate of apprenticeship in firms active in the oil and gas industry. Almost 50 percent of firms in the Norwegian oil and gas industry have a workforce in which half of employees hold a certificate of apprenticeship. This is in sharp contrast to other oil-related clusters, such as Houston, where a significant proportion of the labor force lacks relevant training in terms of academic degrees or technical accreditation.

Figure 5-7: Workforce with a certificate of apprenticeship (left) and commercialization tasks (right) (2008)



Sources: IRIS/BI Survey

Commercialization has not been a primary activity for most of the oil and gas industry. Less than 20 percent of firms have more than 60 percent of their employees focused on sales, marketing and customer relations, while 62 percent of firms have between 1 percent and 20 percent working in sales, marketing and customer relationship activities. As different sectors in the oil and gas industry have reached different maturity levels, the diminishing returns on innovation have led firms in some sectors to focus more on exploitation through commercialization. We will explore this hypothesis in section 5.3.

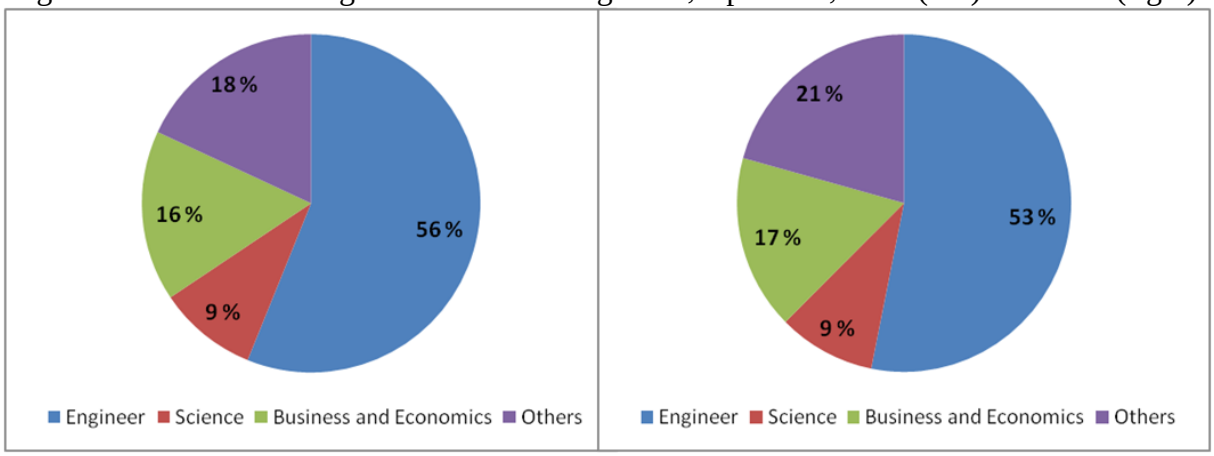
5.3 Types of education per sector

We now turn our attention to the traits of the specific sectors that comprise the oil and gas industry. Our main focus is the composition of each sector in terms of employees' higher education backgrounds (including education on the Bachelor, Master or PhD levels) divided into: engineers, science, business and economics, and other fields. The growth rates for these educational fields are also presented.

5.3.1 Operators

Operators have a slightly higher proportion of engineers and scientists than the overall industry. This is particularly evident in terms of employees with a science background, where the share is almost twice as high as in the whole industry (Figure 5-8). Of all sectors, Operators show the most stable and uniform growth in the workforce and the growth rate is among the lowest in the industry. Unless the Operators leverage their knowledge to other competitive arenas, this trend is expected to continue, in which case growth rates will flatten out or decline.

Figure 5-8: Division of higher education background, Operators, 2002 (left) and 2008 (right)



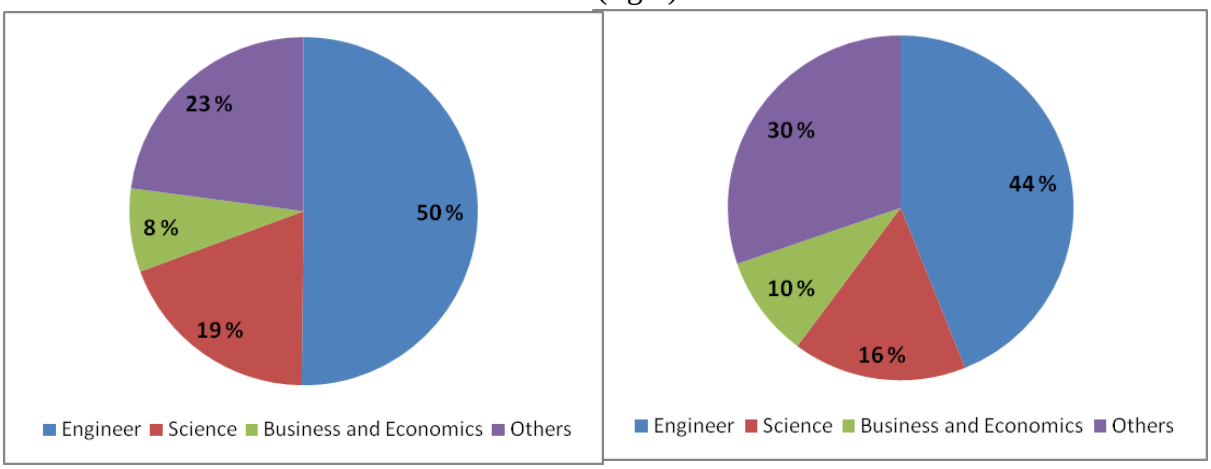
Sources: Statistics Norway, IRIS/BI

For Operators, growth rates for the four types of educational backgrounds follow industry-wide growth, where the growth of engineers is the lowest and the growth of others is the highest. The overall growth rate of others notably exceeds that of engineers (Figure 5-8). Firms in the Operator sector have few employees working in sales: 89 percent of firms have 10 percent or less of their workforce involved in sales activities. This composition may change, as the share of engineers is declining and more none-core activity workers have backgrounds in business, economics or other fields.

5.3.2 Geo & Seismics

The Geo & Seismics sector is host to the most science-heavy labor pool in the oil and gas industry (Figure 5-9). This is not surprising given the type of services that it provides and its strong connections to basic research milieus, such as the Norwegian University of Science and Technology (NTNU).

Figure 5-9: Distribution of higher education background, Geo & Seismics, 2002 (left) and 2008 (right)



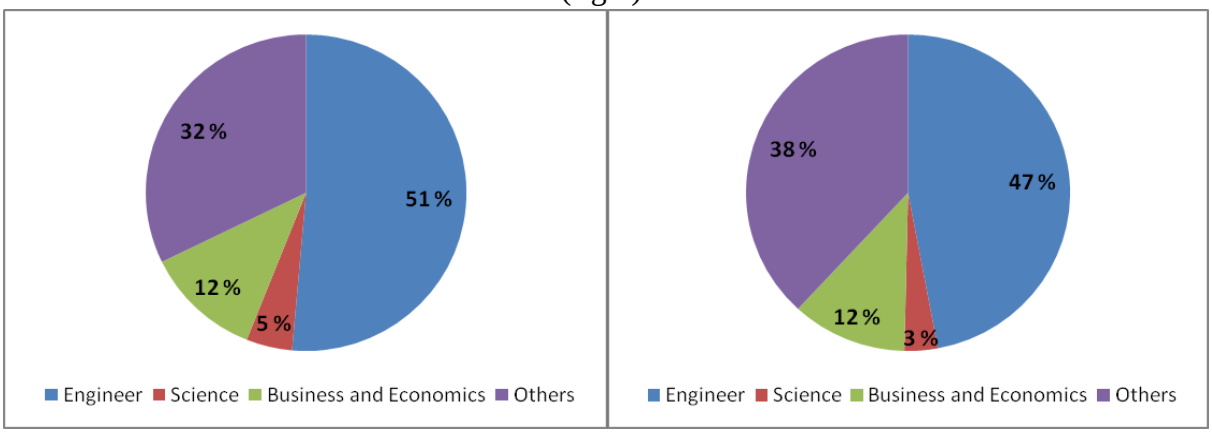
Sources: Statistics Norway, IRIS/BI

Geo & Seismics firms have focused on the recruitment of a workforce educated in business, economics and other social sciences. The number of workers performing support activities in the sector has grown significantly. Inventions and innovations in this sector began rather early when compared to the timing of developments in the Subsea sector. The significant increase in the workforce with business and economics degrees and other social science degrees over the last eight years may indicate a shift from the development of new products and services to the commercialization of already developed products and services. With a lower expected activity level on the NCS, firms may have the opinion that selling off-the-shelf solutions is a more economically viable strategy than continuing to invest in tailor-made solutions or in new technologies.

5.3.3 Drill & Well

Drill & Well's workforce is nearly identical to that of the oil and gas industry as a whole (Figure 5-10). By its very nature, this sector combines advanced engineering development with an emphasis on a competent sale force. This combination is required to facilitate the numerous external relationships needed to support the high export level that characterizes this niche.

Figure 5-10: Distribution of higher education background, Drill & Well, 2002 (left) and 2008 (right)



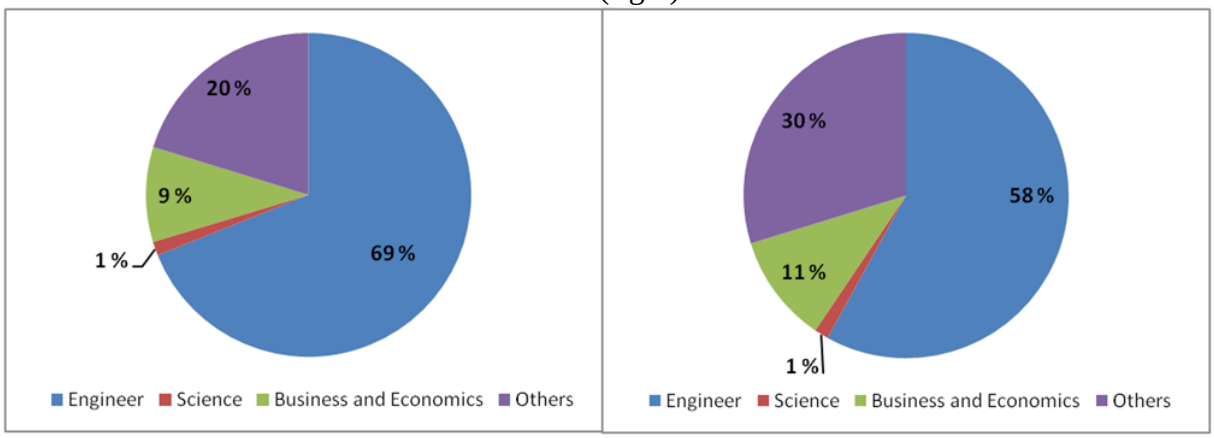
Sources: Statistics Norway, IRIS/BI

The Drill & Well sector has experienced the highest growth rate in terms of employment over the last eight years. In addition, the sector has experienced the lowest decline in the percent of engineers relative to the university-educated workforce employed in the sector. In absolute terms, the Drill & Well sector has also experienced the highest increase in the percent of engineers, which indicates that engineering competences are migrating from other parts of the industry and from other industries into Drill & Well. We focus further on intra-industry flow in chapter 9. In contrast to the trend observed in many other sectors, the growth rate of the workforce with other types of education is only moderate.

5.3.4 Topside

Topside is one of the biggest sectors in the oil and gas industry. Its educational composition, however, differs significantly from that of the overall industry and Operators. With an unprecedented 58 percent of its university-educated labor pool having an engineering background in 2008, it is the most engineer-heavy sector in the industry. At the same time, only 11 percent and 1 percent of the sector's university-educated workforce have backgrounds in business and economics or science, respectively (Figure 5-11).

Figure 5-11: Percentage division of higher education background, Topside, 2002 (left) and 2008 (right)



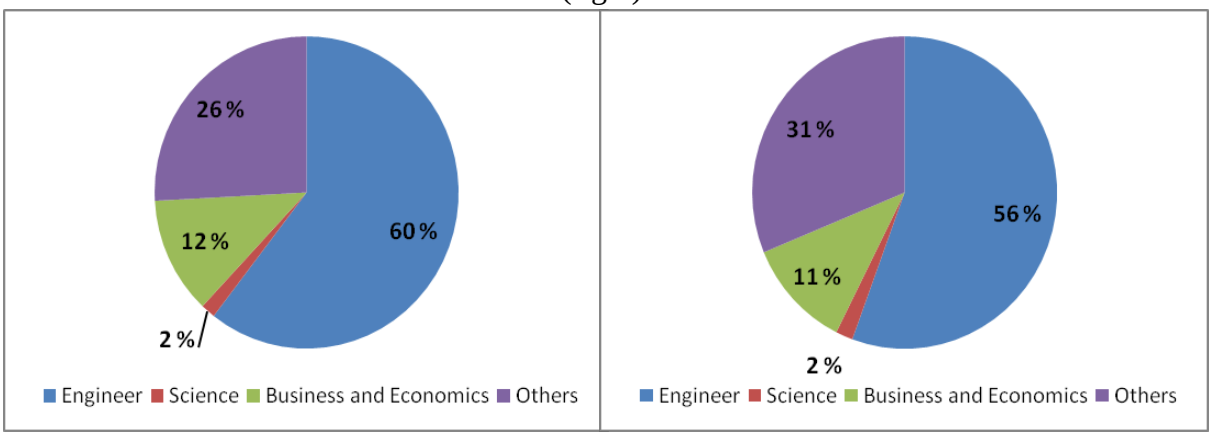
Sources: Statistics Norway, IRIS/BI

The growth of the Topside University-educated labor pool has been led by employees with science or business and economics degrees. Even within this engineering-dominated sector, the trend is similar to that observed in other sectors. Employment growth rates are highest among employees with other degrees and lowest for employees with engineering degrees. The growth rate for engineers from 2002 to 2008 is slightly below the industry average. A more troubling fact is that the employment of engineers in this sector was almost unchanged over the period 2005 to 2008. This provides further evidence of a change in the industry that may be explained by the employment of talented employees with business and economics degrees, and, in particular, of talented employees with other social science degrees. This indicates a lack of qualified personnel, an expectation of decreasing return on investments in engineering-based projects or the offshoring of engineering activities abroad.

5.3.5 Subsea

Subsea is yet another sector that relies heavily on engineers. With only slightly higher levels of science or business and economics-educated employees than Topside, Subsea developed from a very small sector in 2000 into a workplace for more than 3,250 people in 2008 (Figure 5-12).

Figure 5-12: Distribution of higher education background, Subsea, 2002 (left) and 2008 (right)



Sources: Statistics Norway, IRIS/BI

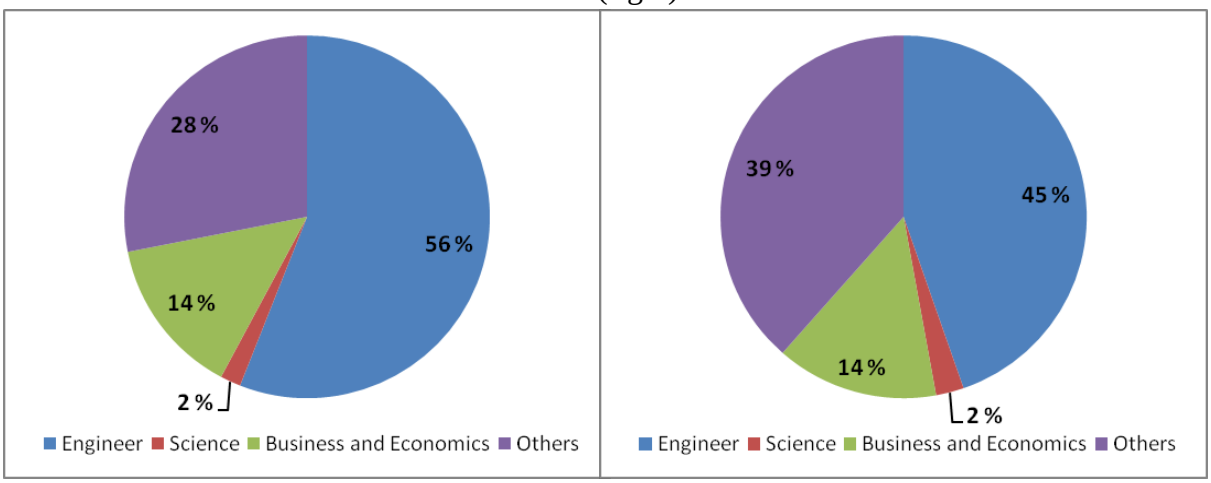
Having experienced the largest growth of all the sectors in the investigated period, Subsea is the up-and-coming sector in the Norwegian oil and gas industry. Both the engineering and science workforces have experienced growth over the last eight years, and the business and economics workforce has grown even faster. Subsea works at the frontier of emerging solutions for more cost-effective extraction of oil and gas, with specific cost advantages for smaller fields. The active Norwegian oil fields offer a pristine market for subsea activity.

Subsea has a relatively low degree of firms with large sales departments: 50 percent of firms have 10 percent or less of their workforce employed in sales, and 39 percent of firms have between 10 and 20 percent of employees working in sales. The remaining 11 percent of firms employ between 20 and 30 percent of their workforce in sales. After comparing Subsea to the more mature sectors of Topside and Geo & Seismics, one might predict changes in workforce composition over time as more workers become engaged in commercialization activities.

5.3.6 Operations Support

Operations Support is another sector with characteristics similar to the overall oil and gas industry (Figure 5-13). However, this sector displays very different growth patterns than those of the other sectors, which all enjoyed uninterrupted growth throughout the entire period. Operations Support experienced a decline in engineers from 2002 to 2003, and an almost flat growth rate for business and economics-educated employees over the same period. The sector's focus has changed dramatically from engineering inventions and engineering-based modifications to general support activities. During the period of analysis, the proportion of engineers decreased by 11 percent, while the proportion of employees with other educations increased equivalently. Currently, 39 percent of Operations Support firms have sales departments that employ more than 30 percent of the firm's total workforce. 38 percent of firms have 10 percent or less of their total workforce active in sales. The remaining 23 percent of firms have between 10 percent and 30 percent of their total workforce working in sales.

Figure 5-13: Distribution of higher education background, Operations Support, 2002 (left) and 2008 (right)

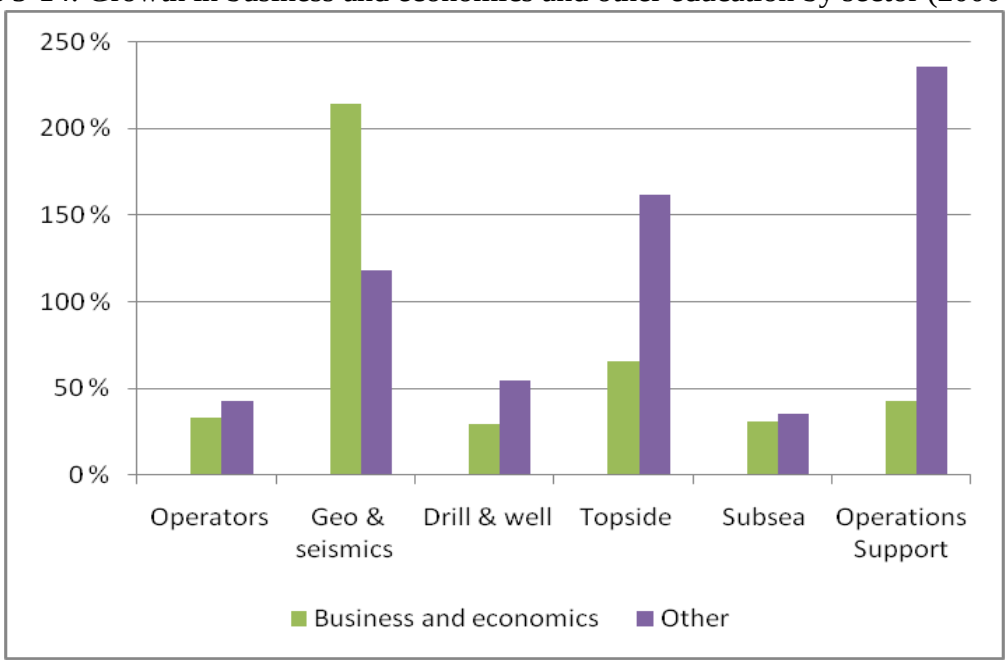


Sources: Statistics Norway, IRIS/BI

5.3.7 Types of education per sector: Conclusion

In summary, the growth in the proportion of engineers has not been homogeneous across sectors, which has significant implications for the future development of the industry and its various sectors. Figure 5-14 summarizes the findings with respect to each sector for the period 2002 to 2008. In the figure, a growth rate of zero percent indicates that the growth rate of employees with business and economics or other education was the same as the growth rate of engineers. Hence, zero is the reference point (the growth rate of engineers in each sector is set equal to zero). Subsea and Drill & Well have been attracting engineers and growing tremendously in this respect over the period. Growth rates in the rest of the industry are flattening out and, in some cases, the number of engineers is constant or declining.

Figure 5-14: Growth in business and economics and other education by sector (2000-2008)

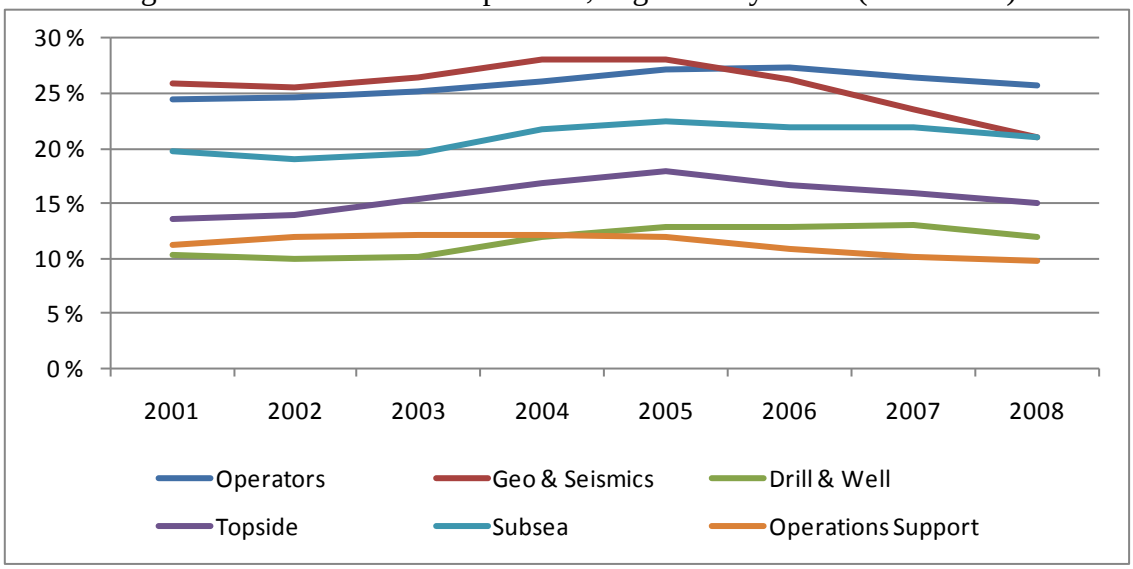


Sources: Statistics Norway, IRIS/BI

In the Geo & Seismics sector, the growth rate for business and economics-educated employees was three times the growth rate for engineers. Operations Support and Topside

grew by three times as much as engineers in terms of hiring an educated workforce with other types of university education. Relative to the growth rates for engineers, the growth rates for business and economics and other university-educated employees in Subsea and Drill & Well (the growth sectors) and Operators (the nucleus of the system) were also higher than in other sectors.

Figure 5-15: Workforce composition, engineers by sector (2000-2008)



Sources: Statistics Norway, IRIS/BI

Figure 5-15 supports the findings reported in Figure 5-14. The figure shows the percentage of employees with an engineering education as a proportion of the total employees per sector. Similar to the relative growth of engineers to the growth of business and economics and other university-educated employees, we observe that the Geo & Seismics, Topside and Operations Support sectors have not only professionalized their operations but that they have also decreased their relative focus on engineers. The growth sectors of Drill & Well and Subsea have maintained their relative focus on engineers. Growth may, therefore, be associated with increased sales and not an increasing importance of engineering.

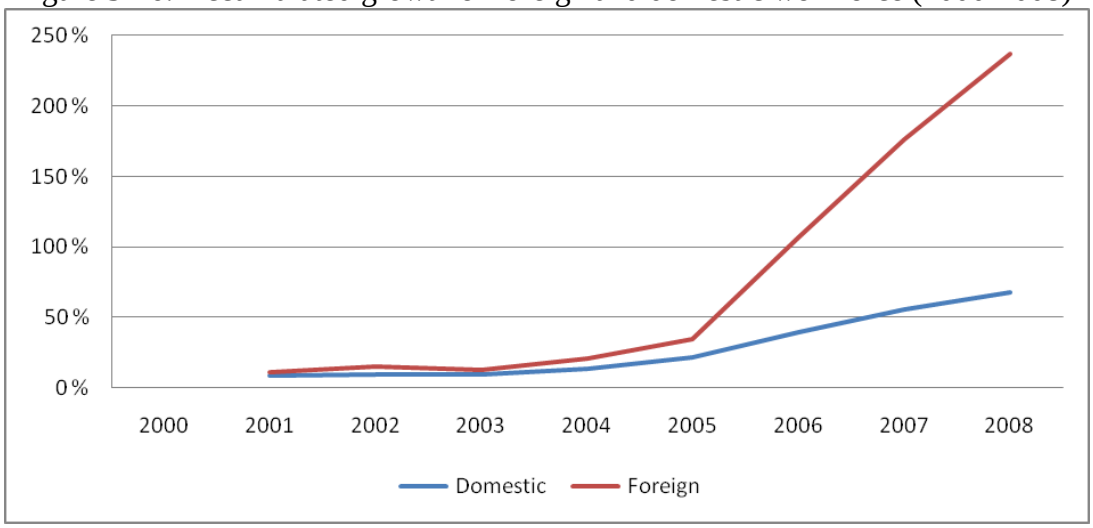
The industry trend has been to increase the relative share of employees with commercialization knowledge and general support activities. These figures depict a gradual change in workforce composition and strategic positioning within the industry. The three apparent mechanisms – the lack of qualified personnel, an expectation of decreasing returns on investments in engineering based projects or the offshoring of engineering activities – are likely to negatively affect the sustainability of the Norwegian oil cluster.

5.4 Foreign labor

An attractive industry is also able to recruit foreign talent. The foreign labor workforce has increased remarkably from 4 percent of the total workforce in the industry in 2000 to 8 percent in 2008.[30]

[30] A large proportion of foreign workers have not declared their educational level. Therefore, a conclusive verdict on the development of the foreign labor force's educational level cannot be reached.

Figure 5-16: Accumulated growth of foreign and domestic workforce (2000-2008)



Sources: Statistics Norway, IRIS/BI

Figure 5-16 plots the accumulated growth of both the domestic and foreign workforce. The largest increase in the foreign workforce is observed starting in 2005, at which point residents of the new EU/EEC countries were given access to the Norwegian labor market on the same grounds as other EU/EEC residents. The vast majority of the new foreign workers in the industry originate from relatively less advanced economies, such as Poland. From 2005 to 2008, growth in the number of Polish workers increased 4.8 times the expected rate. Their share of total employment in 2008 was 0.9 percent. The number of workers from India grew five-fold and the number of workers from Russia grew by 360%. Both constituted 0.3 percent of the total workforce in 2008. By comparison, in 2005 the four largest nations contributing to the Norwegian workforce in the oil and gas industry were the United Kingdom (1.7 percent), Sweden (1.3 percent), Denmark (1.1 percent) and the US (0.9 percent). In 2008, however, their relative shares were still at 2005 levels.[31]

5.5 Talent attractiveness: Conclusions

The industry has closed the gap relative to the national education level. However, it does not attract more specialized labor than is available in the overall population. The industry has gone through a professionalization process over the last decade in that six percent of workers with only a high school or middle school education were replaced with university graduates. Many engineers work in the oil and gas industry, although their share is declining in several sectors, including Topside, Geo & Seismics and Operations Support. The most obvious growth in these sectors is among workers with business and economics and other social science backgrounds. If this trend continues, parts of the cluster may move from exploration and the creation of new, engineering-based products and solutions towards the exploitation of already developed products and solutions or towards less engineering focused, more labor-intensive work, such as MMO. The trend is also apparent in the proportion of engineers in Subsea and Drill & Well, which remains constant while we would have expected an increase.

[31] The findings with regards to regional talent attractiveness are reviewed in section 2. Regions differ noticeably in their specializations. With regards to the attractiveness of engineers, we observe that Oslo/Akershus, Buskerud and Sør-Trøndelag are most effective in attracting such a workforce, while Rogaland and Hordaland have slightly lower concentrations of engineers.

Finally, the industry has attracted many foreign workers in recent years. However, most were hired on the basis of the cost advantages associated with these workers rather than their specialized knowledge.

6 R&D and innovation attractiveness

Research and innovation play central roles in economic progress and in shaping the trajectory of societal development. In this regard, a debate fueled by Norway's low percentage of gross expenditure on R&D (1.6 percent) relative to total Norwegian GDP of has been underway for some time. On the one hand, some argue that Norway spends on R&D as New Zealand, another country rich in natural resources, and hence its R&D expenditure is in line with its industrial structure. On the other hand, some argue that Norway is failing to utilize its resource richness to invest in future innovation that would provide continued funding for the high standard of living and the relatively expensive social welfare system. In this chapter, we provide evidence that the oil and gas industry, which generates the most income from a Norwegian natural resource, is substantially more research-intensive and innovative than other Norwegian industries.

Since 2004, the OECD has focused on what it has coined 'the Norwegian puzzle'. The question is the following: Why does Norway have one of the highest rates of labor productivity among OECD countries and very high per capita income – even when correcting for income from oil and gas production – when it consistently scores poorly on standard indicators of innovation and R&D (OECD 2008)?[32] The OECD has shown that if the oil and gas industry was excluded from the Norwegian economy, i.e., if Norway had the same industry structure as the average OECD country, it would have the fourth-highest R&D intensity of the OECD countries (OECD 2008). The answer to the question must therefore lie in the way that R&D and innovation are measured in the oil and gas industry.

A number of reports have shown that the reason why the oil and gas industry scores poorly on conventional R&D and innovation indicators is because R&D and innovation in the oil and gas industry are not confined to a lab. Instead, R&D and innovation in the oil and gas industry are part of 'everyday business practice' and are, therefore, not recorded in the financial accounts as 'R&D expenses' (AFF 2003; TEKNA/OLF 2006; Koch and Hauknes 2007; NESTA 2007). Furthermore, TEKNA/OLF (2006) argues that the nature of the measurements used in the innovation index means that the innovativeness of Norway, in general, and of innovation in clusters like the oil and gas industry, in particular, are underestimated. Furthermore, the nature of innovation among firms in a cluster and the reduced importance of patenting in a relationship-based innovation system like in the oil and gas industry, also contribute to a generally low innovative score.

It should be mentioned that when measuring R&D and innovation, the OECD confines the 'oil and gas industry' to companies registered with NACE codes 6 (extraction of oil and gas) and 9.1 (support activities). As this report uses a wider definition of the supplier industry, the results on R&D and innovation are not comparable.

[32] The OECD had previously focused on another puzzle, the so-called "Swedish paradox", in which Sweden had high scores on R&D and innovation indicators but its GDP per capita was only average (OECD 2008: 54).

Case: Innovation in ConocoPhillips Norway

ConocoPhillips is the operator for several fields in the Ekofisk area, and is one of the largest foreign operators on the Norwegian continental shelf, with 1,900 employees and a production of 196,000 barrels of oil equivalents per day (2009, including production in partner-operated fields).

The Ekofisk field. Photo: Kjetil Alsvik/ConocoPhillips

Innovation in ConcoPhillips comes about through a combination of three channels. First, as the company's day-to-day operations take place along the borders of what is technologically feasible, continuous improvements in operations is regarded as the 'main engine' for innovations. Second, problems that can not be handled by the operative units are handled through a continuous improvement process (based on Six Sigma) called 'Good to Great', that takes a structured approach to find solutions and also invites knowledge sharing from other units worldwide or from specially designated company experts. Through this 'Good to Great' process and internal knowledge sharing, the company recently managed to enhance production by understanding the process of how barium sulfate scale was deposited inside production wells. Third, problems seen to require more long-term efforts are handled by own R&D or by funding external R&D projects which in some cases involves master's- and/or PhD students.

This process of knowledge generation is administered by a steering committee that each month reviews operative challenges and decides which challenges should be worked through 'Good to Great' and which should be the subject of more long-term R&D projects. The committee also monitors progress and estimates the monetary value of all projects. While the annual R&D budget for ConocoPhillips Norway is approximately NOK 110 mill, the value of internal knowledge sharing could amount to several hundred mill. NOK but is not registered as R&D in company accounts.

This chapter starts with a look at some of the major innovations associated with oil and gas exploration on the NCS, and argues that the activity on the NCS has functioned like a giant laboratory for the development of new technologies. The following section shows how Norway has established strong R&D units in universities and in the private sector.

6.1 The development of the Norwegian petroleum innovation system

The Norwegian oil and gas 'adventure' was launched in 1962 when the US oil firm Phillips made an enquiry with the Norwegian embassy in Germany about the possibility of exploring for oil on the NCS (Kvendseth 1988; Ryggvik 1997). As Norway did not possess competences related to essential technologies like drilling, reservoir modeling and field development, the Norwegian government decided to invite global oil firms to Norway. However, Norway did possess considerable expertise in mining (geology), process industries, maritime operations and construction (yards), and personnel from these fields soon became part of the burgeoning Norwegian supplier industry (Hagen 2001). As offshore petroleum activities were not well developed anywhere in the world in the mid-1960s, Norwegian competencies in maritime operations proved particularly helpful in carving out a niche for Norwegian-based companies (Heum 2008).

> "When the first exploration vessels came to Stavanger, Toralf Smedvig [a large regional ship owner] and his shipping engineers went aboard. Most of the technologies aboard were familiar to them, but they also took note of modifications that would be necessary for vessels to handle the North Sea." CEO, Venture capital firm

To secure national value creation from oil and gas activity, the Norwegian government introduced procurement policies favoring a Norwegian-based, but not necessarily Norwegian-owned, supplier industry in 1972 (Heum 2008).[33] The Ministry of Petroleum and Energy had the right to require that specific Norwegian firms be added to operators' bidder lists, but in only one case, in 1982, did the Ministry openly reject an operator's choice of supplier. However, the operators were kept generally well informed about the Ministry's views through informal exchanges (Nordås *et al.* 2008). In addition, up until 1985, the Norwegian government ensured preferential treatment for state-owned Statoil in the awarding of production licenses (Ryggvik 1997). In 1979, in the fourth licensing round, the government introduced provisions for technology cooperation between foreign operators and Norwegian research institutions and Norwegian-based firms. At first, it was required that at least 50 percent of the R&D necessary to develop a field in Norway should be undertaken by Norwegian institutions. This requirement was then replaced with 'goodwill agreements' under which foreign operators had to make an effort to conduct as much oil and gas R&D in Norway as possible. The 'goodwill agreements are seen as a major factor in the growth of the Norwegian R&D sector (institutes like IRIS, SINTEF, etc.) (Engen 2009).

By the early 1980s, the Norwegian oil and gas industry had gained significant ground and a generation of petroleum-educated Norwegians began to appear. This began what Ryggvik (1997) refers to as the 'Norwegianization' of multinationals with Norwegian personnel taking over most positions in foreign-owned operators and supplier companies.

The industrial policies of the 1970s and 1980s are now widely recognized as 'infant industry' protection (Reve *et al.* 1992; TEKNA/OLF 2006). This feature is one that the Norwegian oil

[33] The procurement policies did not affect the maritime industry, which was viewed as fully internationally competitive.

regime shared with other European oil and gas producers in the 1970s. For example, in the UK, the government also played an active role although, in contrast to Norway, the UK industry was deregulated earlier (Engen 2009). The Norwegian industrial policies were discontinued in 1994, as they were believed to be in breach of the European Economic Area's (EEA) competition laws. However, by that time, both Norwegian-owned operators (Statoil, Hydro and Saga) and Norwegian-based suppliers had been established.

The Norwegian experience with 'infant industry' protection has its own special features. First, while oil countries like Mexico and Brazil (until the early 2000s[34]) focused on providing work for nationally-owned companies (Nordås *et al.* 2008), the Norwegian focus on national value creation led to an extensive collaboration with multinational companies (Heum 2008). Second, the Norwegian procurement policies were known to be handled gently with a notable amount of informal exchange of views taking place (Heum 2008). Taken together, this may be seen as a case of how 'subtle' state activism may help to boost an industry.

> "[T]he key to Norway's industrial success has not been protection, but to arrange for a dynamic industrial and technological development that involves competent actors within the domestic knowledge base and leading international competence." (Nordås *et al.* 2008)

> "[T]hat America's industrial successes have been free of any taint of government encouragement, support or coordination […] is not true of today's triad of high-tech wealth generators: information technology (fostered by the Defense Advanced Research Projects Agency), genomics and biotechnology (fostered by the National Institutes of Health), and geospatial and GPS application (fostered by the military)." Letter to the editors (Foreign Policy 2011)

At present the Norwegian government provides incentives for oil and gas-related research and innovation through four channels:

1) 'Accounting agreements' in the petroleum tax system for operators. The special petroleum tax of 50 percent levied on top of the ordinary tax rate of 28 percent for all income from licenses from the NCS implies that operators only pay 22 percent of any investment in Norway. As long as the NCS provides operators with large-scale projects with significant income streams, the special petroleum tax rate makes investments in high-tax Norway relatively more profitable than investments in other oil provinces. As an incentive for R&D and innovation, the Accounting Agreements ['Regnskapsavtaler'] specify that all R&D expenses with relevance for exploration, field development or production on the NCS may be charged to the license accounts,[35] which, in effect, reduces R&D costs by 50 percent (the special petroleum tax).

2) The SkatteFUNN policy for all industries. The SkatteFUNN policy (established in 2002) gives any Norwegian-based firm that meets certain conditions the right to a tax deduction of 20 percent of R&D expenses, up to a maximum of NOK 11 million per year. In 2009,

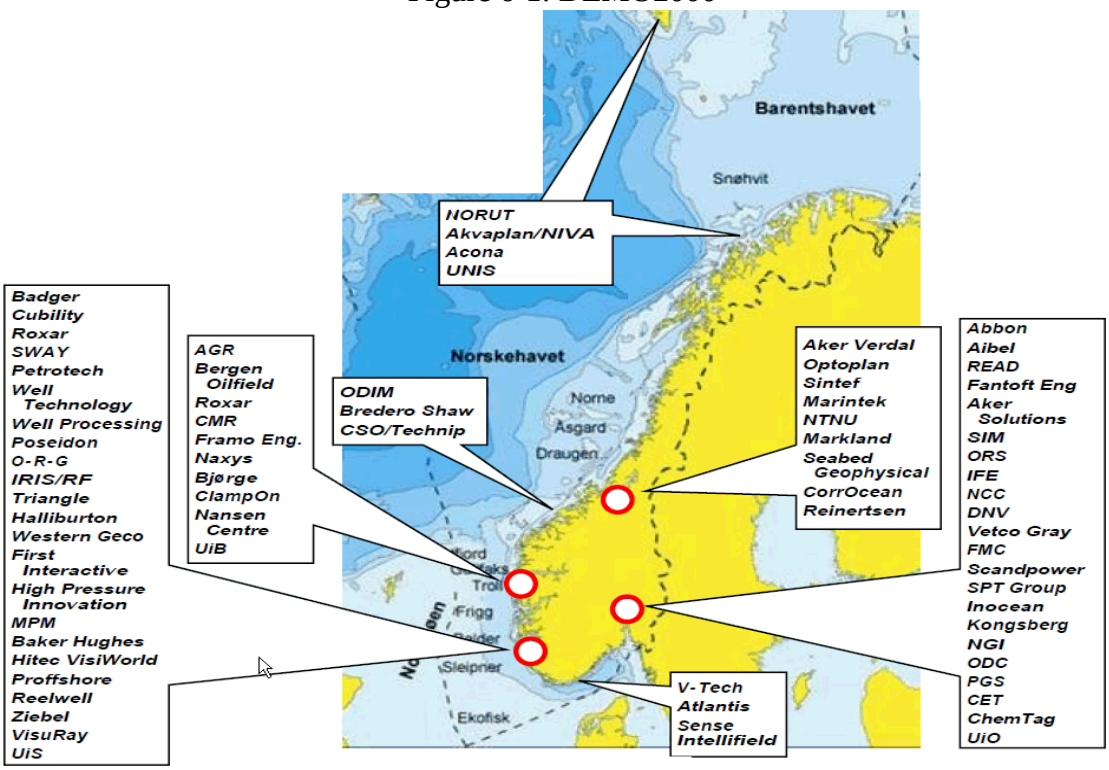
[34] In the first decade of the 2000s, Brazil changed its industrial policies. It is now working systematically to strengthen national industrial capacity while allowing for foreign competition (Heum *et al.* 2011).

[35] The activity does not have to be related to a project with relevance for the license to which it is charged.

SkatteFUNN contributed NOK 170 million to oil and gas-related research and innovation (Ministry of Petroleum and Energy 2010).

3) Innovation funding through Innovation Norway and SIVA. Firms in the Norwegian oil and gas industry may apply for innovation funding from Innovation Norway. In addition, SIVA and Innovation Norway, together with the Research Council of Norway, are financing the development of regional oil and gas clusters through the NCE and Arena programs.

Figure 6-1: DEMO2000



Source: Amended from Kjelaas (2009)

4) Research funding from the Research Council of Norway (RCN). First, the RCN is funding petroleum-related research through the PETROMAKS and DEMO 2000 programs, which had 2010 budgets of NOK 231 million and NOK 98 million, respectively.[36] Second, the RCN's 'Industrial PhD' program (introduced in 2008) funds parts of company-related PhD programs. Of the current 77 PhD programs, 14 are related to the oil and gas industry, mainly in the areas of geophysics and geological modeling/simulation.[37]

For DEMO2000, Figure 6-1 shows how the current petroleum innovation system may be seen as networks clustered around the four major R&D centers: the University of Oslo/Institute for Energy Technology (IFE), the University of Stavanger/IRIS, the University of Bergen/CMR and the University of Trondheim/SINTEF.

[36] The government-appointed task force OG21 (Oil and Gas in the 21st Century) provides recommendations on directions for research to the Ministry of Petroleum and Energy.
[37] Of the 14 PhD projects related to the oil and gas industry, 9 are related to geophysics and geological modeling/simulation, 2 are related to operations support, 2 are related to drill and well, and 1 is in organizational psychology (Research Council of Norway, 2011).

6.2 Innovations on the Norwegian continental shelf

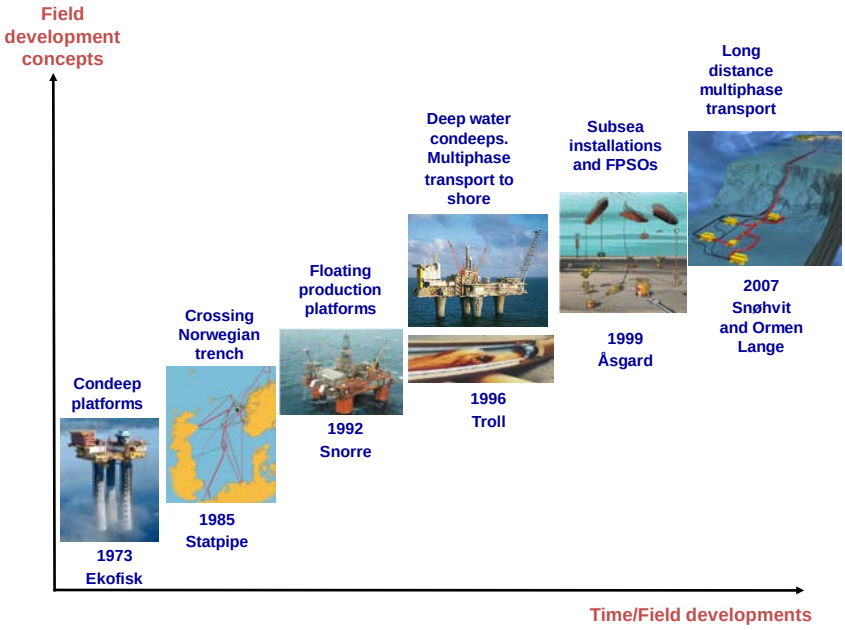
The preceding sections of this report covered the evolution of the Norwegian petroleum innovation system in the course of almost 40 years. This part will look at the system's outcomes in terms of innovations related to field development concepts and improved oil recovery. An important finding is that major technological breakthroughs have been precipitated by practical challenges, often related to a major field development.

Field development

The first innovation in field development concepts came in the early 1970s when Norwegian engineers at Norwegian-based yards successfully constructed the first concrete offshore platform, the Condeep.[38] This innovation helped Norway's traditional shipyards become builders of offshore facilities.

The laying of a pipeline (Statpipe) across the Norwegian trench from Stafjord to mainland Norway (Kårstø), back across the trench again and into Norpipe (Germany) made it possible to move gas onshore in Norway. Another innovation significantly reduced costs – the introduction of floating production platforms without processing facilities, where production was either transported to shore (gas) or to neighboring installations (oil). This innovation came in response to the increasing costs on the NCS. The first floating production platform, the Snorre A, came into use in 1992.

Figure 6-2: Innovations on the NCS related to field development



Sources: Adapted from TEKNA/OLF (2006) and Fjose et al. (2010a)

The construction of a condeep for deep water with multiphase transport directly to shore was a major innovation. The prerequisite for multiphase transport was the development of OLGA, a program for managing multiphase flows, which was undertaken by SINTEF and the Institute for Energy Technology (IFE). In 2005, Statoil estimated that multiphase transport

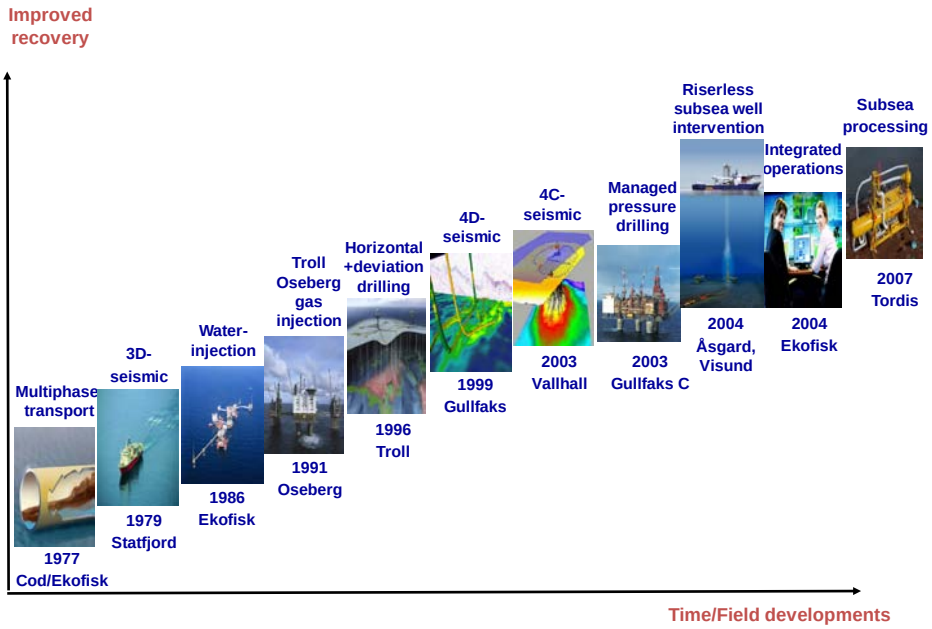
[38] The first condeep was the Beryl A platform in the UK sector, which implies that the export market came before the home market (Fjose *et al.* 2010a).

from platform to shore had improved the net present value (NPV) of Troll by NOK 30 billion (NTVA 2005: 69).

The introduction of subsea installations and floating production ships (FPSOs) at the Åsgard development helped keep costs down and helped make marginal fields economically feasible. The development of Snøhvit and Ormen Lange was based on multiphase transport to shore in very deep waters (800 to 1,000 meters) and over long distances. The development of these fields was the result of improvements in the management of multiphase flows and improved knowledge about conditions on the seabed, which were relevant for the laying of a pipeline.

In addition to economically feasible field development concepts, another major challenge in terms of oil and gas production is the rate of recovery, i.e., the amount of resources that may be extracted from reservoirs. When Ekofisk, Norway's first oil field, was discovered in 1969, the rate of recovery was estimated at 17 percent. However, after a number of successive innovations, the rate of recovery is now at around 50 percent. On average, the rate of recovery of all fields on the NCS is about 46 percent (Ministry of Petroleum and Energy 2010). Fjose et al. (2010a) estimate that innovations from 2000 to 2009 increased the rate of recovery by 1.7 percentage points for oil, NGL and condensate, and by 0.1 percentage points for gas. Therefore, these innovations yielded an increase of NOK 144 billion in total NPV. The observed increases in rates of recovery are the result of a number of successive innovations.

Figure 6-3: Major technological breakthroughs related to improved oil recovery on the NCS



Sources: Adapted from Ministry of Petroleum and Energy (2010) and Fjose et al. (2010a)

The Cod field was developed so that the three phases of the well stream – oil, gas and water – were sent directly to the Ekofisk field for processing. This necessitated the first major innovations related to the management and surveillance of 'multiphase' transport.

The multiphase transport innovations were followed by the development of 3D seismic, which allows for three-dimensional reservoir measurement and represents a quantum leap in

reservoir management. This development was, to a large extent, pioneered by Norwegian-based firms (PGS, TGS and WesternGeco).

Water injection to offset falling pressure in the reservoirs was pioneered by Ekofisk in 1986. This innovation is seen as decisive in the increase in Ekofisk's rate of recovery from the originally planned 17 percent to the current 46 percent (Ministry of Petroleum and Energy 2010).

Gas injection, as pioneered at Troll and Oseberg in 1991, also served to improve reservoir pressure and is assumed to have yielded extra resources of 300 mill scm of oil equivalents (Ministry of Petroleum and Energy 2010: 36). Furthermore, the development of horizontal and deviation drilling, i.e., intelligent rotary drilling systems, made it possible to reach thin reservoirs, like Troll oil, which are "pancakes" of oil underneath giant gas reservoirs. This technology was developed by a partnership among BakerHughes, Inteq and Hydro, and was tested at IRIS's test facilities in Stavanger.

WesternGeco's development of 4D seismic, i.e., 3D seismic imaging repeated over time so that time becomes the fourth dimension, allowed for seismics to be used as an instrument in the optimization of production. 4D seismic helps locate water fronts and is therefore useful for optimizing drilling in fields where water injection is being used. In addition, the laying of permanent seabed cables/sensors (4C seismics) for continual seismic data acquisition has been used at Valhall and at Statoil's field in the Tampen area. However, industry insiders generally feel that 4C has not yet had a significant effect on oil and gas recovery.

One major reason for lower recovery from subsea wells is the enormous cost of subsea well intervention, which requires that a rig be towed into place and anchored above the well. FMC Technologies developed a technology for vessel-based well intervention and the Norwegian-owned shipping firm Island Offshore helped to develop vessels as platforms for that technology. Island Offshore Subsea, which manages the intervention vessels, estimates that vessel-based intervention of subsea wells reduces the costs of well intervention by two thirds, i.e., by 2-3 million NOK per well.

Subsea processing, i.e., the shift in processing and injection from surface to seabed, has recently been touted as an important innovation in terms of improving recovery from subsea wells. The technology was installed at the Tordis field with the aim of increasing recovery by 6 percentage points but the projected improvement failed to materialize, as the formation did not have the capacity to absorb the injected water. However, the field's operator, Statoil, sees subsea processing as a promising focus for technological development in the years to come.

The transport and catering of personnel offshore is very costly and, together with the Norwegian system of offshore rotation, is an important explanation for the high extraction costs on the NCS. The establishment of operations centers for ICT-based onshore surveillance of offshore operations in the early 1990s was an important step in reducing the costs of offshore operations. With the laying of fiber optical cables to offshore installations, communication improved. Onshore operations centers (Integrated Operations) have since become an industry standard. Whereas a well stimulation may have previously required one week offshore, the whole operation may now be completed from a home office in less than five hours. An OLF (The Norwegian Oil Industry Association) report states that Integrated Operations have the potential to increase the NPV of all fields by more than NOK 300 billion (OLF 2007).

This discussion of the major innovations on the NCS shows that most innovations have been connected to solving practical challenges related to large field developments. As the Norwegian petroleum innovation system allows operators to charge R&D expenses to their license accounts, the size of the field developments has created enough scale for significant R&D and innovation activities.

A report on oil and gas innovations commissioned by the Ministry of Petroleum and Energy argues that almost all of these innovations came about as the result of a close collaboration between Operators and Suppliers (Fjose *et al.* 2010a). R&D institutions also played a role, but their contribution often preceded the actual innovation by several years. For example, basic research conducted in the early 1980s became the building blocks for the development of subsea technology in the mid-1990s (Noreng 2004).

6.3 Current Norwegian petroleum innovation system

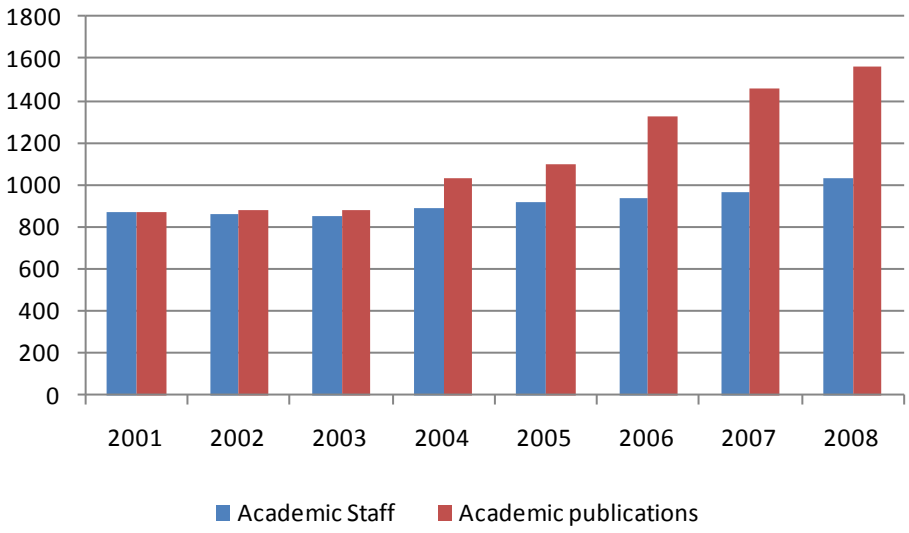
As is evident in sections2 and 3, the Norwegian petroleum innovation system consists of academic R&D, firm R&D and various collaboration constellations. In this section, we review the performance of academic and firm-specific R&D, while collaborations are discussed further in Chapter 9.

6.3.1 Academic R&D

In order to investigate the productivity of industry resources, we examine the development of the number of publications, the number of academics in related fields working within academic institutions and their productivity in terms of publication activity. OECD uses a similar measure – the number of scientific publications per million population – as a measure of R&D investment outputs. All else equal, the number of publications is a good proxy for the return on investment in the educational sector. Academic publications constitute a platform upon which commercialized innovation can occur. However, as scientific output is not a commercialized invention or innovation, we view it as an input rather than as an output (commercialized activity) to the two major objectives of economic progress and the shaping of society in the future.

The number of academic publications in academic subjects related to the oil and gas industry doubled from 2001 to 2009. There was linear growth in the number of publications during the same period, which corresponds to the increase in the number of academics working in relevant subjects. As is evident in Figure 6-4, the number of academic staff increased by 19 percent from 2001 to 2009, while the number of publications increased by 99 percent.

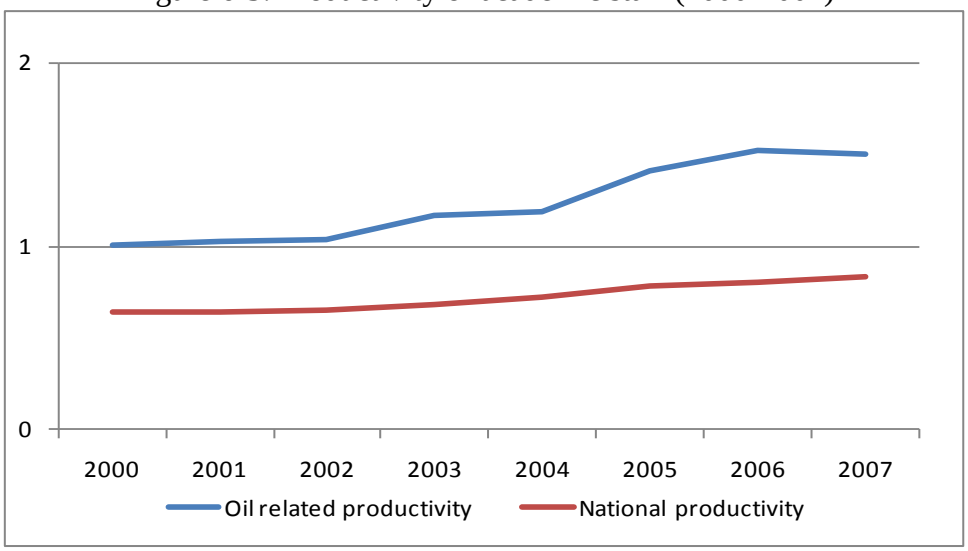
Figure 6-4: Academic staff and publications (2001-2008)



Sources: ISI Web of Science, NSD, IRIS/BI

This increase in productivity appears to have flattened out, although it should be noted that academics focusing on oil and gas-related fields and publishing on industry relevant subjects are about twice as productive as their colleagues in other academic departments. Figure 6-5 illustrates that academic productivity (the number of published articles per academic per annum) increased by approximately 50 percent over the period 2000-2008.

Figure 6-5: Productivity of academic staff (2000-2007)



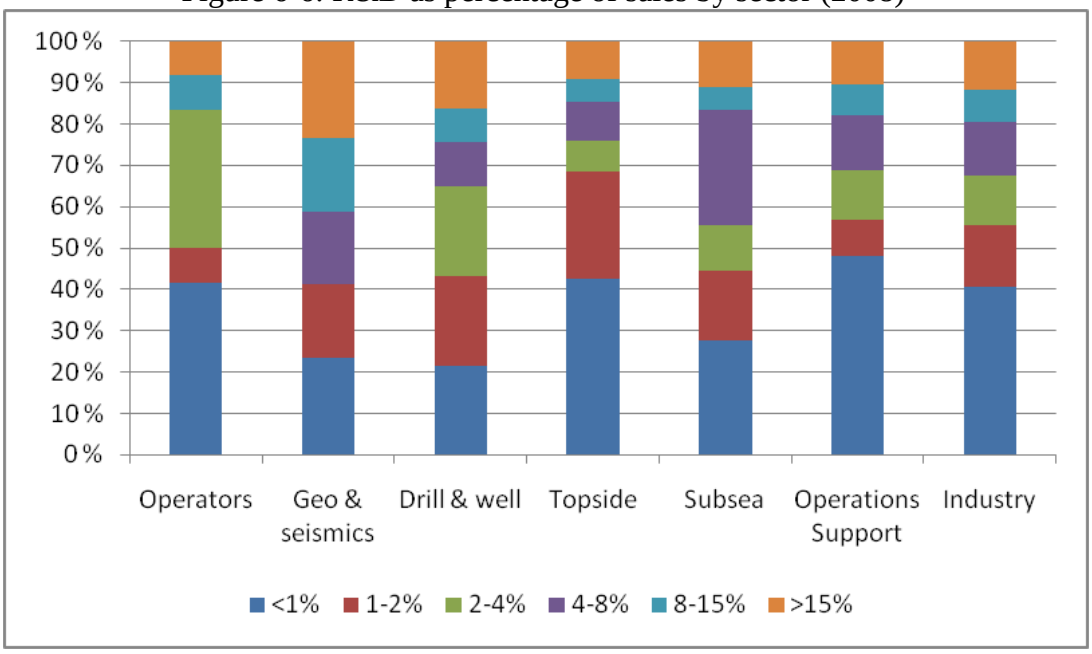
Sources: ISI Web of Science, IRIS/BI

6.3.2 Firm R&D

To what extent can firms tap into the knowledge base residing within dedicated R&D institutions? We commence with an analysis of the ratio of R&D investments to sales before we examine firm investments in R&D personnel. The former is commonly used as an indicator of R&D intensity (March 1991). The higher the share of R&D relative to sales, the more likely a firm is to explore new territories. Lower R&D as a percentage of sales indicates a focus on the exploitation and incremental amendment of already developed solutions.

It should be noted that Norwegian accounting principles provide a distorted picture of actual investments in R&D. The book value of intangible assets, mostly the estimated value of goodwill and intellectual property rights, constitutes merely 3.5 percent of total assets of firms in the oil sector. In fact, the median firm has no intangible assets. This number has been relatively constant throughout the last four years. The Norwegian accounting standards, therefore, are in sharp contrast to US accounting law, which demands clear reporting of R&D expenditure. As they are inadequate for examining actual investments by Norwegian-based firms in R&D, we use two complementary sources: the Knowledge-Based Norway Oil and Gas Survey conducted in 2010 and the multiple Innovation and R&D Survey conducted by SSB.

Figure 6-6: R&D as percentage of sales by sector (2008)



Sources: Statistic Norway and IRIS/BI

The majority of firms within the oil and gas industry invest less than 2 percent of their sales in R&D, while 12 percent invest more than 15 percent of their sales in R&D. R&D intensity differs substantially in accordance with the type of activity conducted. 40 percent of Operators and Topside firms utilize less than 1 percent of their sales for R&D. In comparison, only 20 percent of Drill & Well firms invest less than 1 percent of sales in R&D. About 50 percent of firms within Geo & Seismics and Subsea activities invest more than 4 percent of sales in R&D (Figure 6-6). It should be noted that the use of sales as the denominator makes it difficult to compare operators and suppliers due to the inflating effect of income from sales of oil and gas.

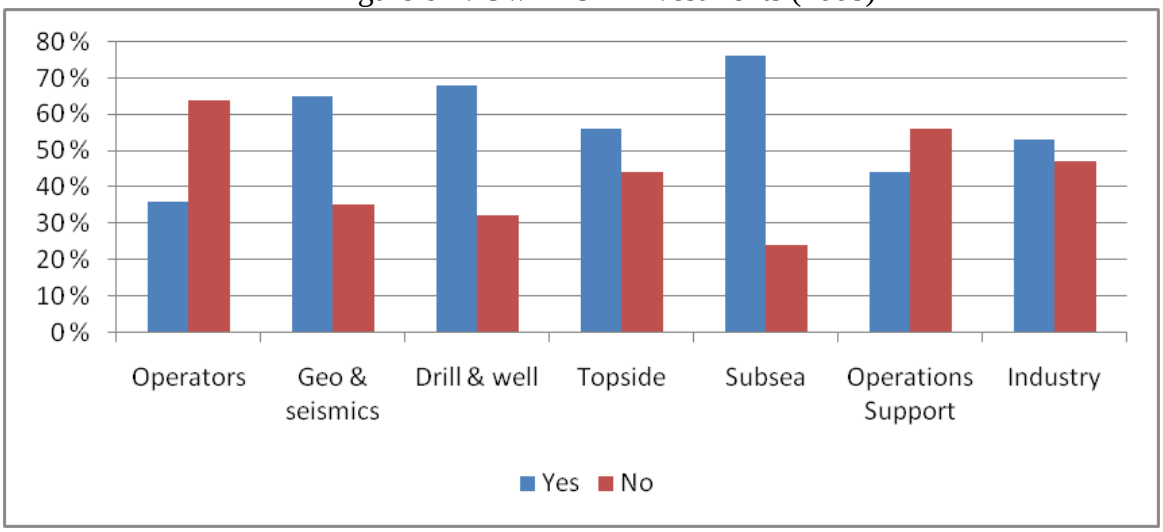
Case: Schlumberger Norway

Schlumberger is one of the world's leading oilfield services providers. It focuses on improved E&P [exploration and production] performance for oil and gas companies. Through well site operations, and in its research and engineering facilities, Schlumberger is working to develop products, services and solutions to optimize customer performance in a safe, environmentally sound manner.

Following its merger with Smith and MI-SWACO in 2010, Schlumberger grew to more than 2,850 employees in Norway. Around 750 employees are involved in some aspect of the R&D value chain. In 2008, more than 10% of Schlumberger's total worldwide R&D budget was spent in Norway.

Research at the Schlumberger Stavanger Research Center (SSR) focuses on developing cross-disciplinary tools and workflows for geophysical reservoir characterization and monitoring through the automated analysis and modeling of subsurface measurement data. Scientists with backgrounds spanning the spectrum of the seismic-to-simulation workflow develop solutions for the Norwegian continental shelf, the Gulf of Mexico and offshore Brazil. SSR, together with the North Sea GeoMarket offices and the R&D department of WesternGeco, constitutes Schlumberger's global Center of Excellence for four-dimensional (4D) seismics and reservoir characterization. All new seismic acquisition technology for the Schlumberger group is developed in Norway, including the Petrel seismic-to-simulation software, and Ocean, Schlumberger's open software development environment that offers seamless integration of client IP into Petrel mainstream workflows.

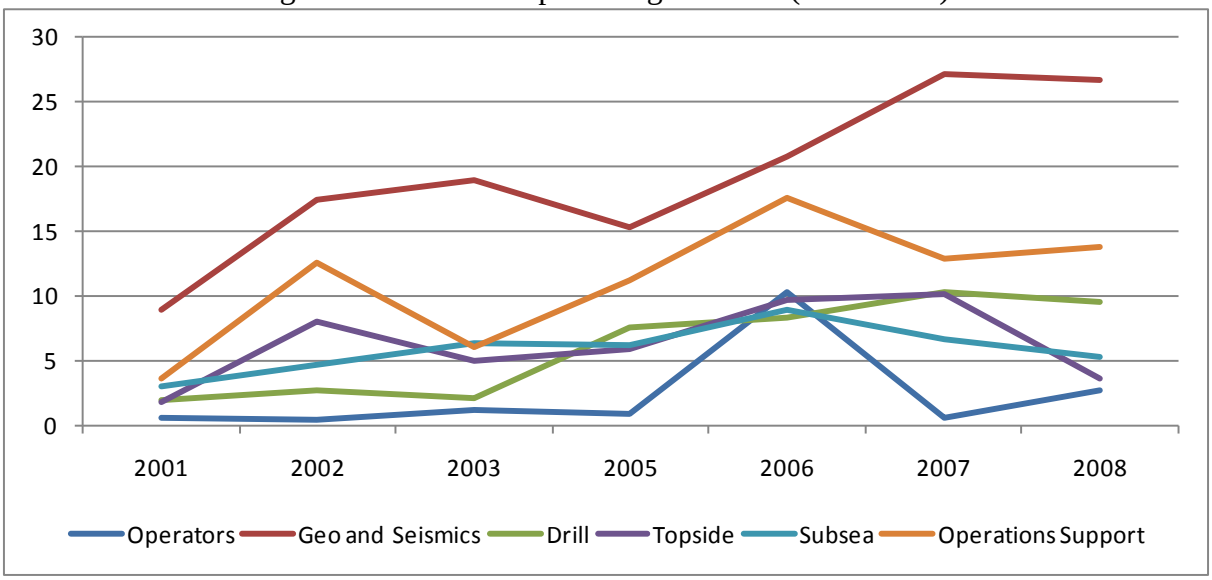
Figure 6-7: Own R&D investments (2008)



Sources: Statistic Norway and IRIS/BI

When we examine direct R&D investments (Figure 6-7), a different pattern emerges. 45 percent of firms within the oil and gas industry as a whole make no R&D investments whatsoever and 62 percent of Operators do not conduct R&D activities. The situation is the opposite for suppliers in technologically advanced niches. For example, only one firm out of five in the Subsea sector does not conduct R&D internally.

Figure 6-8: R&D as a percentage of sales (2001-2008)



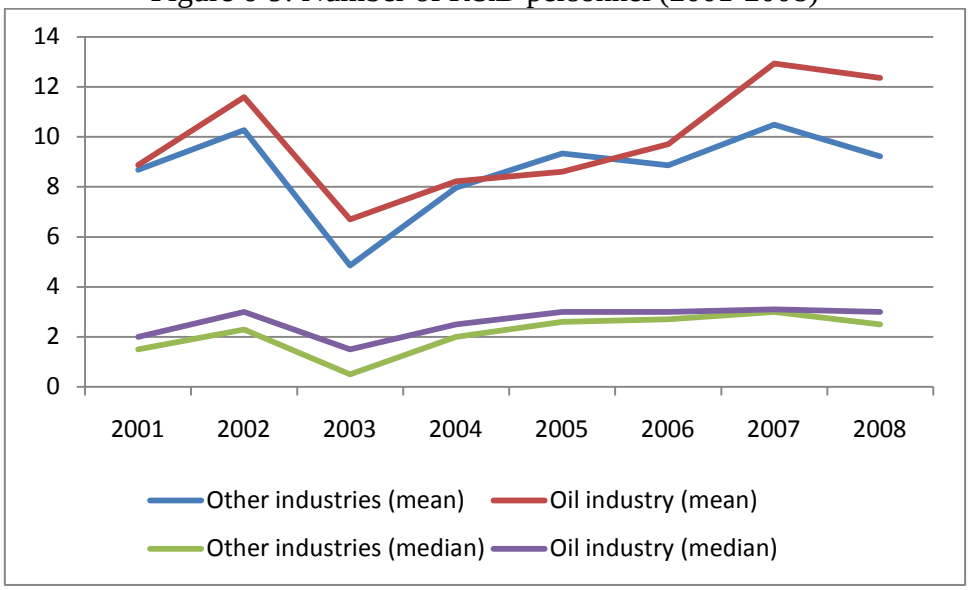
Sources: Statistic Norway and IRIS/BI

In order to corroborate findings originating from the Knowledge Based Norway Oil and Gas Survey, we examine the internal R&D costs as reported to SSB in the Innovation and R&D Survey. Figure 6-8 shows internal R&D costs as a percentage of total turnover within the individual sectors. Operators use less than 1 percent of their turnover on R&D, as suppliers have taken responsibility for R&D activities in the system. The highest expenditures are within the Geo & Seismics sector, which have been increasing and represented 27 percent of total turnover in 2008. Generally, there was an overall increase in the percentage of total turnover used on R&D within each sector from 2001 to 2008. However, most sectors either

maintained or decreased their relative investments in R&D from 2006 to 2008. This may indicate an expectation of decreased returns on R&D investments.

> "We used to import technologies from our headquarters in the US, but this is changing as Oceaneering globally now recognizes the importance of Norway for the development of oil and gas-related technology. Oceaneering Norway has finally been recognized as a provider of technology." Head of Business Development, Oceaneering

Figure 6-9: Number of R&D personnel (2001-2008)

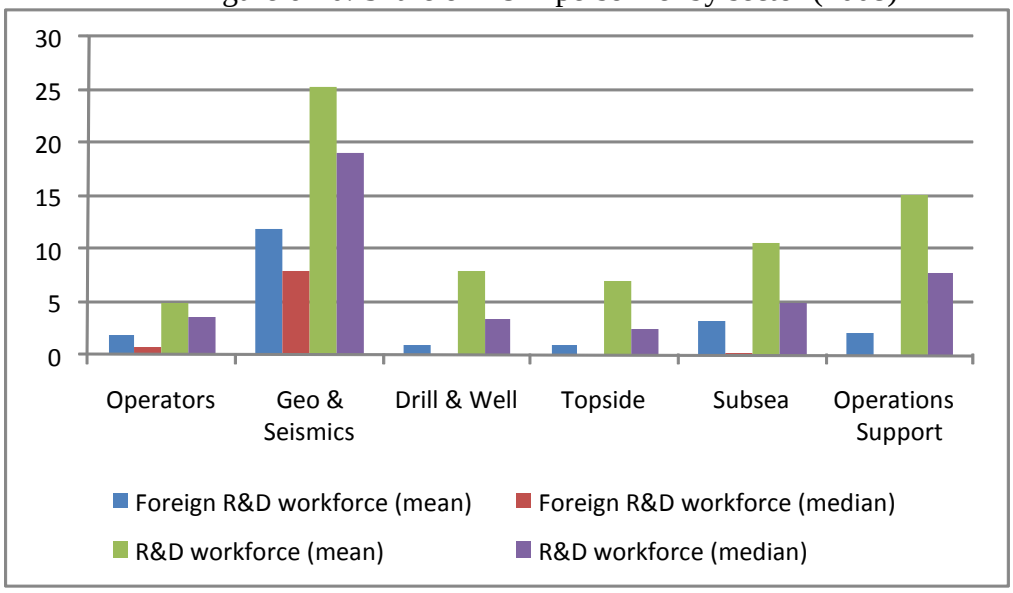


Sources: Statistic Norway and IRIS/BI

One indicator of the capacity for innovation and execution of R&D projects is the total number of R&D personnel and researchers (OECD 2010: 44). Figure 6-9 shows the number of domestic personnel employed in R&D activities within the oil and gas industry and in the rest of the economy. The oil industry has a slightly higher average amount of employees employed in R&D activities per firm. However, the trends in the oil industry follow that of the other industries: the median is low (from 2 to 3), it remains relatively constant, and it is identical for the oil industry and the rest of the economy. The difference between other industries and the oil and gas industry may be explained by the existence of a few large firms within the oil and gas industry that conduct R&D.

The number of foreign employees in R&D has tripled over the last five years. However, the majority of firms do not employ foreign R&D personnel and those that do tend to be larger firms. Figure 6-10 shows domestic and foreign R&D personnel relative to total employment with respect to the major sectors. Generally, domestic R&D employees are the major contributors within the oil and gas industry as a whole. The highest numbers of R&D employees are found within the Geo & Seismics and Operations Support. Geo & Seismics firms also have a notable amount of foreign employees within R&D. Comparably, Operators have the lowest demand for R&D-based innovation and, therefore, the lowest mean number of employees in R&D.

Figure 6-10: Share of R&D personnel by sector (2008)



Sources: Statistic Norway and IRIS/BI

Case: Halliburton Norway

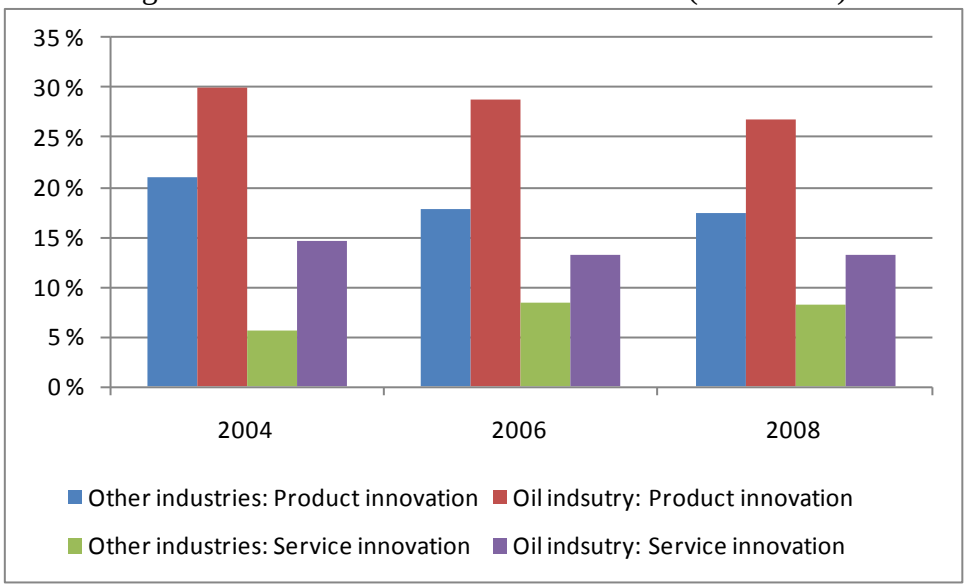
Halliburton is one of the world's top suppliers to the upstream oil and gas industry. It is active in almost 70 countries in the areas of Drill and Evaluation, and Completion and Production.

Halliburton established a Norwegian subsidiary in 1966. Today, the subsidiary employs 1,500 people. Halliburton Norway is recognized for its competence in operations, while Halliburton USA is known for its development of technology. The latter is responsible for most of the group's R&D. Halliburton Norway aims to conduct more R&D projects and to export solutions to other Halliburton units around the world. The Swell Packer solution was developed by the Halliburton Norway subsidiary Easy Well Solutions and is now distributed worldwide by Halliburton USA.

6.4 Current innovative capacity

How innovative are oil and gas firms relative to firms in other industries? As argued above, actual R&D expenditure may not be a good proxy for innovative output in the oil and gas industry. Innovation is affected by investments in R&D but such investments are not the only basis for innovation. The distinguishing characteristic of a cluster is its superior ability to create conditions under which innovative output can materialize. The Norwegian oil and gas industry provides strong support for theories indicating the existence of a link between the clustering of commercial activity and innovative output.

Figure 6-11: Product and service innovation (2004-2008)



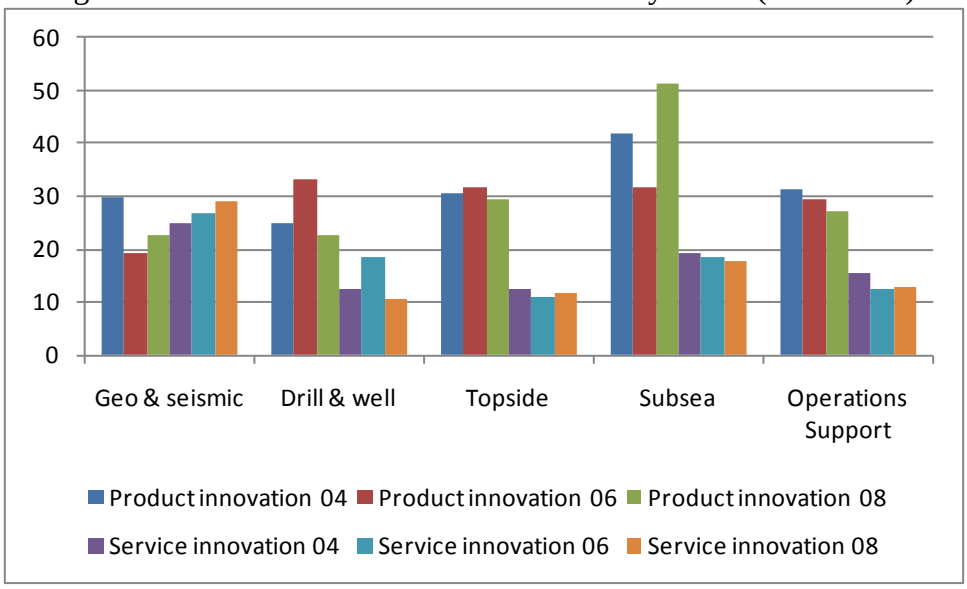
Sources: Statistic Norway and IRIS/BI

Figure 6-11 shows the amount of product innovation in the form of new or significantly improved goods introduced by the firms from 2004 to 2008. The figures represent a percentage of total answers. The oil and gas industry demonstrates more product innovation than other industries, with the positive response rate of 25 percent to 30 percent indicating that approximately every fourth firm has introduced an innovative product.

The percentage of innovative firms is naturally lower for services, which are complementary goods and are of lesser importance than products in this industry. Notably, the overall intensity of product and service innovation for the oil and gas industry appears to be on a decreasing trend, observable as a linear, moderate decline in both product and service innovations. As discussed earlier in this section, most major innovations on the NCS have been responses to practical challenges connected with large field developments with an economic scale sufficient for the funding of significant R&D activities. The observed decline may be a result of a lower number of large field developments, and a corresponding lack of practical problems to be solved and a lack of sufficient scale for funding R&D.

> "As it is now, the areas in which the Norwegian cluster can maintain its technology leadership are diminishing. In the future, the Norwegian cluster will have to capitalize on IOR [improved oil recovery] efforts in Saudi Arabia, and deep water operations and developments in Brazil or the Gulf of Mexico." Head of technology, Petoro

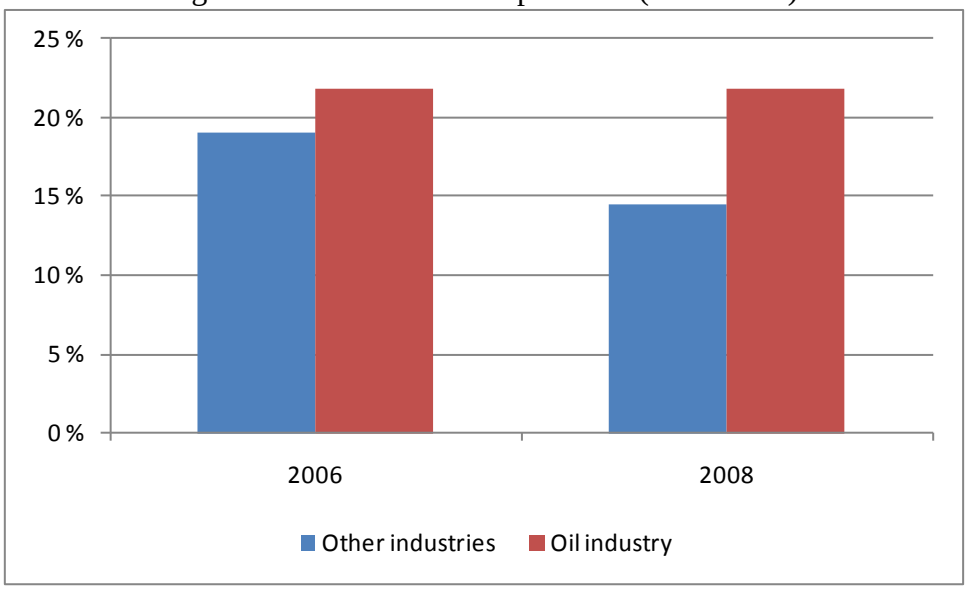
Figure 6-12: Product and service innovations by sector (2004-2008)



Sources: Statistic Norway and IRIS/BI

The pattern of innovative output differs substantially among the different activities, as observed in Figure 6-12. The figure shows the percent of firms in each sector that reported the introduction of a new or substantially improved product or service over a three-year period prior to the date of data collection. The trends indicate that Geo & Seismics firms appear to be shifting focus from product innovation to service innovation. Operations Support also shows decreasing levels of product innovation. Subsea is the only sector that shows an increasing trend in product innovation, although it is not continuous.

Figure 6-13: New business practices (2006-2008)

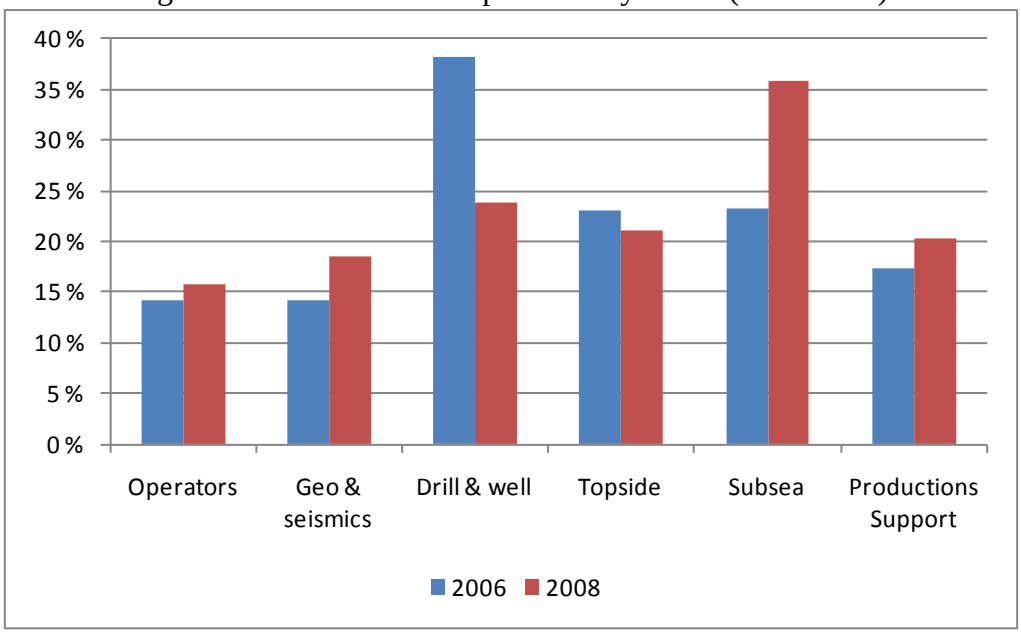


Sources: Statistic Norway and IRIS/BI

Is the oil and gas industry only innovative in terms of product innovations? Figure 6-13 shows the percentage of respondents that had applied new business practices for organizing work and procedures. In this respect, the oil industry remained at a constant level from 2006 to 2008, while other industries experienced a decline. More than 20 percent of firms in the oil industry have applied new practices, making the oil industry very dynamic in terms of

amending the intra-firm rules and procedures that allow it to compete internationally. This can be partially explained by firms' needs to compete globally for contracts and by the local establishment of foreign competitors.

Figure 6-14: New business practices by sector (2006-2008)



Sources: Statistics Norway – R&D and Innovation Survey and IRIS/BI

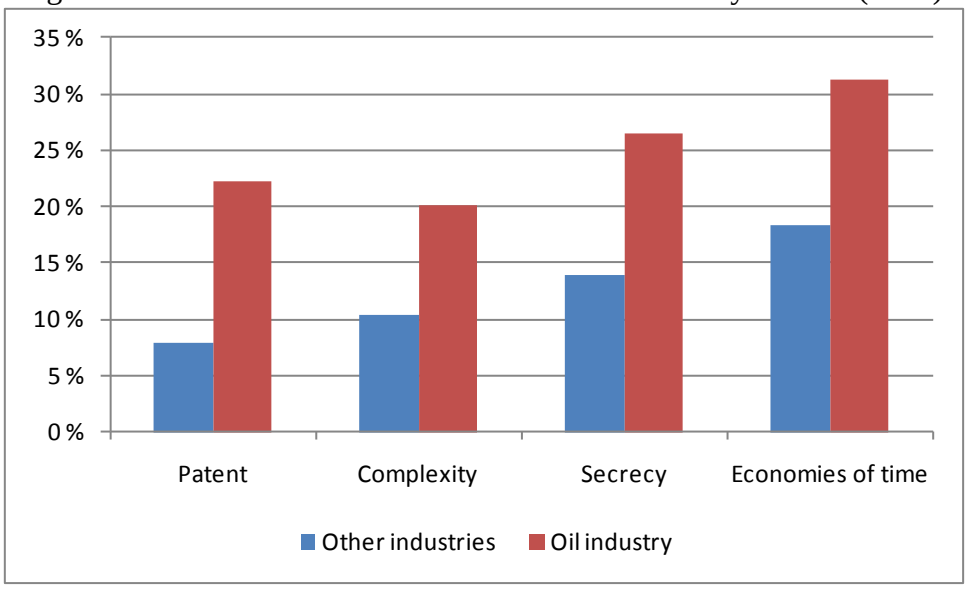
The percentage of respondents in the oil industry that have applied innovations in the area of organizational practices was relatively constant for most sectors from 2006 to 2008 (Figure 6-14). Subsea has experienced the highest growth, as it is a relatively new field compared to the other sectors and there is more room for improvement. Drill & Well has incurred the largest decline, which might indicate that firms in this sector are stabilizing their organization of work and procedures after tremendous growth in sales over the past five years.

6.5 Protecting investments in innovation

The initiation of innovative activity also depends on the extent to which the proceeds of investments can be shielded from imitation by competitors (Barney 1991; Peteraf 1993). We therefore examine the percentage of respondents that have chosen to protect their inventions and innovations (obtained by averaging the percent of positive answers in 2006 and 2008).

Intellectual property is assumed to be protected through the registration of patents. The low utilization of patent protection in Norway has been continuously highlighted in the media and by academics. Common explanations of Norway's relatively low usage are its lack of innovative capacity and its industrial structure, which favors other protection mechanisms. For the oil and gas industry, we find support for the latter explanation. Firms in the oil and gas industry, along with firms in the rest of the economy, rely heavily on other protection mechanisms, such as secrecy, complexity or economies of time. Furthermore, these protection mechanisms are used more frequently in the oil and gas industry than in the rest of the economy.

Figure 6-15: Protection of inventions and innovations by method (2008)



Sources: Statistics Norway - R&D and Innovation Survey and IRIS/BI

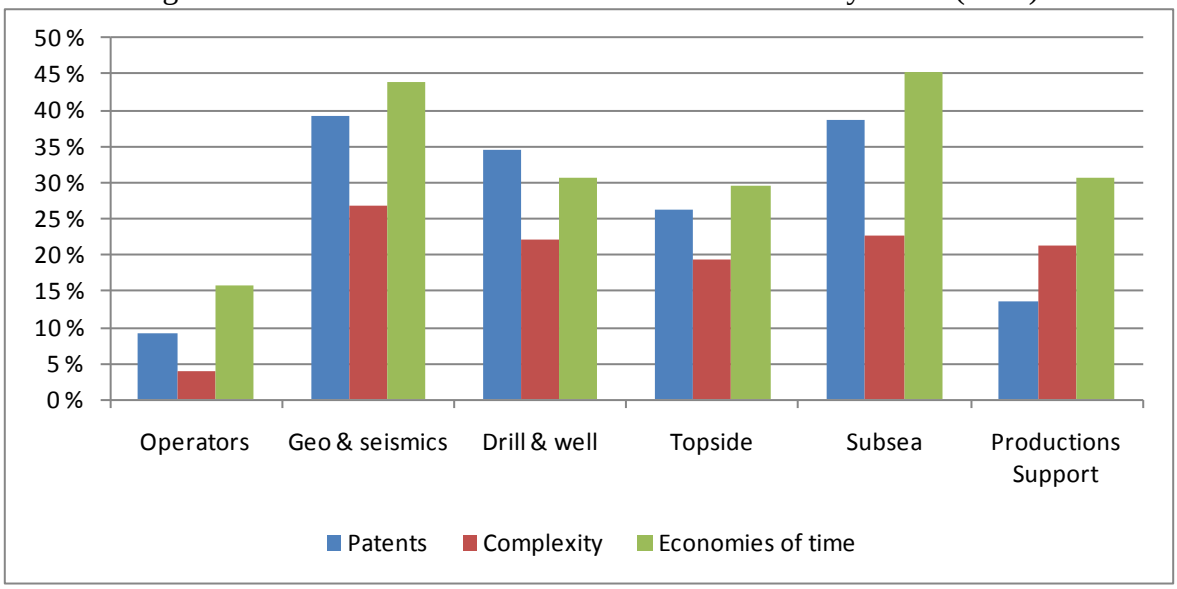
23 percent of all responding firms in the oil and gas industry indicate that they have used patent registration in order to protect their intellectual property rights. Patent protection is almost three times more widespread in the oil and gas industry than in the rest of the economy. When we take this finding into consideration, the oil and gas industry frequently utilizes patent protection, while other Norwegian industries fall clearly below other Scandinavian countries in this regard. The most common explanation for Norway's poor patent performance (e.g., only 25 triadic patent families per million inhabitants in Norway compared to 78 in Sweden) is the structural characteristics of the Norwegian industry. We find some evidence to the contrary. The problem of low patenting in Norway seems to originate from other sectors of the economy rather than those based on natural resources (Figure 6-15).

At the same time, however, the oil and gas industry's primary protection mechanism is not patenting. Protection of innovation through the use of economies of time has been frequently observed in practice (e.g., Intel) and in theoretical discussions (Dierickx and Cool 1989; D'aveni 1995). First-mover advantages (Lieberman and Montgomery 1988; Lieberman and Montgomery 1998) have paved the way to success for a large number of technology-based firms as well as manufacturers of traditional products and retailers. The Norwegian oil and gas industry is no exception. Approximately 30 percent of firms utilize economies of time to protect innovations. The challenge of economies of time as the preferred protective strategy is that it necessitates continuous innovation over time in response to an ever-growing need for more advanced technological solutions or for new solutions to existing problems. These characteristics are typical of an emerging industry or an industry that has to continuously push the technological limits due to increasing demand from customers or projects (e.g., the oil and gas industry).

Hence, relying on continuous innovation without examining the conditions under which such investments can provide positive returns may lead to suboptimal investments. Uncertainty relating to technological challenges in new fields has already affected current innovation strategies. We observe that in some parts of the industry there is a move away from repeatedly recreating the wheel (tailor-made solutions) towards delivering off-the-shelf solutions. In

order to reverse this trend, technological challenges – beyond mere MMO projects – are required.

Figure 6-16: Protection of inventions and innovations by sector (2008)



Sources: Statistics Norway – R&D and Innovation Survey and IRIS/BI

We also explore how firms in the major oil and gas industry sectors protect their inventions and innovations. The numbers shown in Figure 6-16are obtained by averaging the percentage of respondents that answered positively in 2006 and 2008. Respondents in most sectors choose to protect their inventions and innovations through patents and economies of time. Such approaches indicate that firms are reaping the benefits of being first movers. Operators are the least active in utilizing protection opportunities. Less than 10 percent utilize patents and about 15 percent utilize economies of time. These numbers are very similar to the national averages reported in Figure 6-15. The role of Operators in the oil industry is similar to that of a project manager, and these firms, therefore, take on more administrative and coordination tasks where there is less innovation that needs to be protected.

Around 40 percent of firms in the Geo & Seismics and Subsea sectors make use of both patenting and economies of time. These are the technology-heavy sectors and, as previously shown, they have the highest levels of internal R&D expenses. The economies of time strategy is used by 30 percent of Drill & Well and Topside firms. Some of these firms combine labor-intensive and engineering-intensive work in the creation of products and services, so that patents are less likely to be used.

6.6 R&D and innovation attractiveness: Conclusions

Innovations on the NCS related to either field development or improved recovery are mainly the result of practical challenges that need to be addressed. In many cases, innovations come about as a result of close cooperation between Operators and suppliers in large field developments. This innovation system, which is based on solving practical challenges, has given Norwegian-based companies a head start in petroleum technology.

Oil and gas-related academic research in Norway has been growing, both when measured in terms of the number of academic staff and in terms of the number of scientific publications. Norwegian-based firms also conduct significant R&D. 31 percent of all firms use 4 percent or

more of sales on R&D. Furthermore, a number of foreign firms have located their R&D activities in Norway. For example, around 10 percent of Schlumberger's global R&D budget is spent in Norway. Even though these figures are based on a wider definition of the supplier industry, they indicate serious flaws in the OECD's measurement of R&D and innovation in the Norwegian oil and gas industry. Therefore, we find that Norway's persistently high level of productivity and per capita incomes is not really 'puzzling'.

The Norwegian oil and gas industry innovates more than the other Norwegian industries in terms of products, services and organizational practices. Subsea has been very innovative in recent years, while product and service innovations in Topside and Operations Support have declined or remained constant. Being the first to the market with a new innovation is the primary method of protecting innovations in the industry.

If the future holds less activity on the NCS and fewer large field developments, the NCS might become a technological backwater. This may force the supplier industry to look to foreign oil and gas hubs for knowledge and learning. Furthermore, the Statoil-Hydro merger reduced competition on the Operator side dramatically. Both of these developments are likely to push the supplier industry towards constructing a non-Operator-centric innovation system – a formidable task taking into consideration that the system has been Operator-centric for over 40 years. If activity in field development declines and hence the current demanding customers (Operators) become less demanding of novel solutions, Norwegian firms may lose their first-mover advantage. They will then need to find other mechanisms to replace the demanding customer mechanism (Porter 1990; Porter 1998).

> "Most past innovations were driven by the close cooperation between operators and suppliers in the development of the large fields. The current lack of large field developments, the maturation of large oil fields and the prognosis that future discoveries will most likely be small will drive a change in the way we access and implement new technology." Petoro

7 Ownership Attractiveness

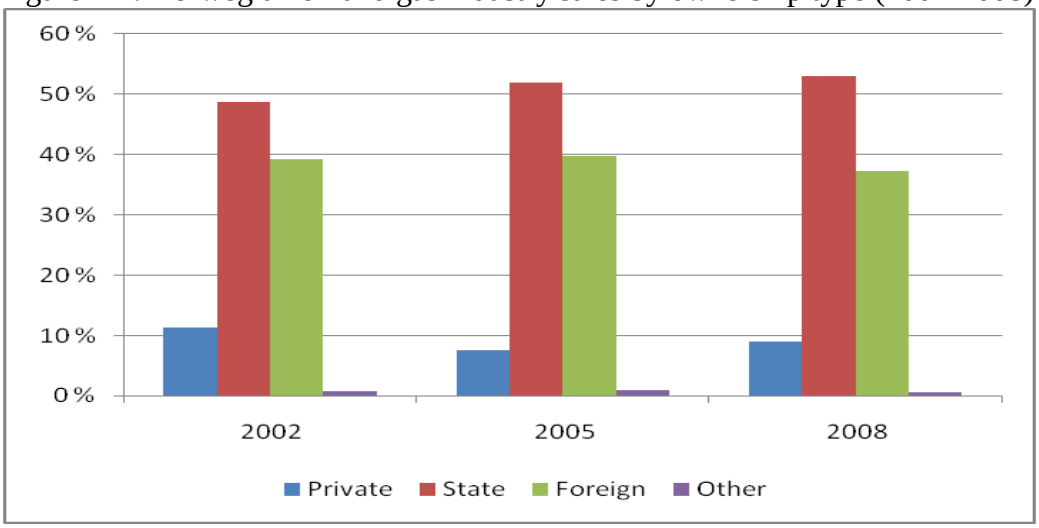
An industry's ownership attractiveness is defined as the extent to which it manages to attract competent capital, either national or foreign, to finance its activities. Emerging industries, such as the biotechnology applications within the health industry in Norway, typically suffer from a lack of competent owners that can competently evaluate new projects. In more mature industries, competent capital is crucial to the financing of innovative and novel projects, and to the injection of fresh capital into existing, growing firms. All else equal, a community of competent owners who are better positioned to offer and understand the benefits of narrow search, easier selection and foresight into the operation of the industry should assist the growth and sustainability of an industry. In this chapter, we analyze the extent to which the Norwegian oil and gas industry manages to attract competent capital.

In the early 1960s, Norwegian policies towards the oil and gas industry focused on attracting global oil and gas operators (Ryggvik 1997). In 1965, the Norwegian-owned industrial group Hydro tried to push the Norwegian government into adopting legislation that would help Norwegian-owned firms accumulate oil and gas knowledge. Hydro's proposals had no effect until 1971 when parliament established the so-called 'ten commandments' for Norwegian oil and gas activity (Recommendation to Parliament no. 294, 1970-1971), which clearly highlighted the need for national supervision and control of the operator side of the industry. The state-owned Statoil was established by Parliament in 1972 and, during the third licensing round, the Norwegian government introduced a requirement that foreign operators transfer competence to Norwegian-owned license holders. As a result, Mobil, the initial operator of the giant Statfjord field, had to train the government-owned Statoil. Parliament then decided that the Statfjord operatorship should be transferred to Statoil, which occurred on January 1, 1987.

While Norwegian ownership became an important issue for the operator side of the industry, the central issue on the supplier side was value creation in Norway, regardless of ownership (Hagen 2001). In 1972, an article on 'Norwegian content' (§ 54) was added to the Norwegian Petroleum Code. The article stated that Norwegian-based suppliers should have preference as long as they were competitive in terms of price and quality (Noreng 2004). 'Norwegian content' was calculated as value added in Norway in both manpower and monetary values. Company ownership was of less interest – what mattered was whether the work was to be carried out in Norway or abroad (Hagen 2001). When applying for new licenses, foreign petroleum firms would be evaluated according to their use of Norwegian-based suppliers.

In the early 1980s, the relationship between states and multinationals shifted. Instead of trying to become independent of multinationals by establishing national operator companies, states realized the need to attract them (Ryggvik, 1997). This was also true of Norway – in both the 11th and 12th concession rounds (1987 and 1988), foreign-owned companies were awarded 43% of total production licenses.

Figure 7-1: Norwegian oil and gas industry sales by ownership type (2002-2008)



Sources: Brønnøysund Register Centre and IRIS/BI

Figure 7-1 shows that the major owner in the Norwegian oil and gas industry in 2008 was the Norwegian state, which controlled 52% of all sales. Foreign owners controlled 37%, while private Norwegian owners controlled 9%. Others, to a large extent trusts, controlled merely 2% of all sales. From 2002 to 2008, the share of state ownership increased, while the shares of private and foreign ownership decreased. This change is most probably due to the increased oil price, which inflated sales of state-owned Statoil.

Figure 7-2: Norwegian supplier industry sales by ownership type (2005 and 2008)

Sources: Brønnøysund Register Centre and IRIS/BI

As seen in Figure 7-2, when operators are excluded and the focus is on the supplier industry, the importance of state ownership diminishes while the importance of foreign ownership increases. In 2008, more than 50% of all sales in the supplier industry were controlled by foreign owners, while only 18% were controlled by the Norwegian state. Private Norwegian ownership was at 28%.

The rates of ownership may be explained in different ways. First, one important reason for the huge reliance on foreign capital is that the Norwegian supplier industry was built with a focus on 'Norwegian content' rather than 'Norwegian ownership' (Heum 2008), and that the industry therefore has a history of relying on Norwegian subsidiaries of global oil service companies like Halliburton, Schlumberger and BakerHughes. Second, another reason for the huge reliance on foreign capital is that foreign-owned companies have been very active in acquiring Norwegian-owned companies. For example, WesternGeco was acquired by Schlumberger, Easywell Solutions was acquired by Halliburton, the Statoil-owned Navion was acquired by Teekay and Multi Phase Meters was acquired by FMC. Third, the relatively low rate of private Norwegian ownership may be due to the lack of a strong community of Norwegian owners.

> "During the financial crisis of 2008, we had problems rolling-over or refinancing our loans. This put pressure on the share price, as investors saw an added financing risk and many investors were already risk adverse. One large Norwegian-based group bought stakes of the firm at a depressed share price and sought to increase its influence in the firm. A few days later, a second industrial firm bought a similar stake. With two industrial investors with large stakes, the firm was 'in play', and hedge funds and other investors were afraid to invest. Management had to aim for the highest possible bid for the firm, and the result was that the firm in its entirety was acquired by a foreign-based group." CEO, oil and gas supplier

The large foreign ownership evident in the supplier industry has been subject to some discussion. Some argue that such buy-outs are meant to contain possible competitors.

> "The pecking order of the oil business is: operators, large suppliers (Schlumberger, Halliburton, BakerHughes, etc.) and smaller suppliers (IKM, etc.). The large suppliers all have the financial muscle to buy interesting start-ups or potentially threatening start-ups." CEO, large Norwegian-owned oil and gas supplier

Others argue that such buy-outs are beneficial, as they give smaller companies access to competent capital and a worldwide distribution network for their products or services.

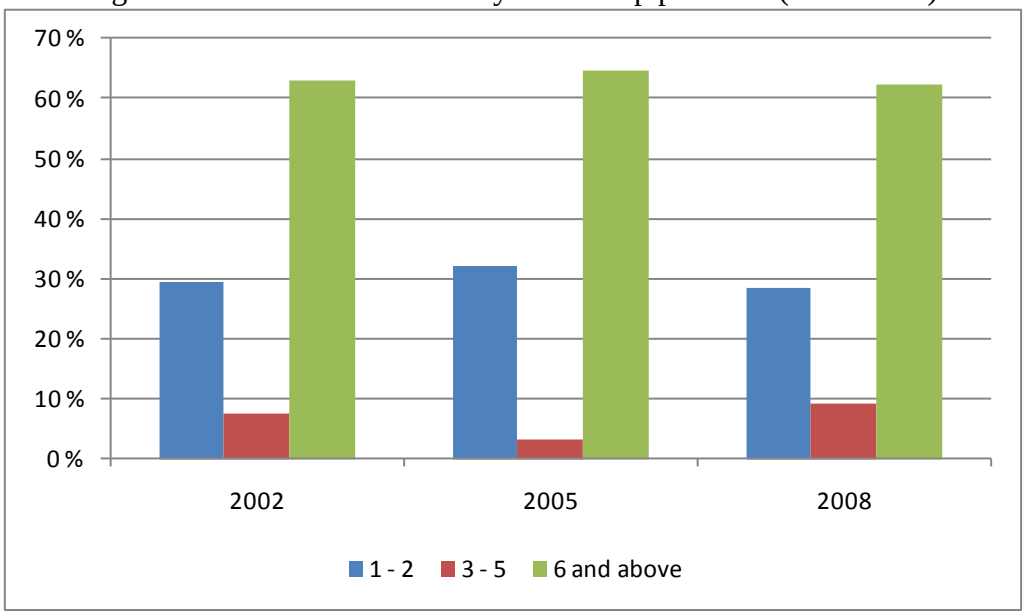
> "The possibility of being bought by a global oil and gas supplier is probably the most important motivator for technological start-ups in the Stavanger region." Head of business development, global oil and gas supplier

Grünfeld and Jakobsen (2006) argue that whether a foreign takeover has negative effects on the Norwegian economy in terms of employment and the location of important headquarter functions depends upon the motive for the takeover. If the takeover is motivated by the acquiring company's need for consolidation, the result may easily be the exodus of important headquarter functions. If, on the other hand, the takeover is motivated by restructuring or business development, the result might be that all important functions are kept and nurtured in Norway. When the Canadian shipping firm Teekay bought the Norwegian-owned firms Bona Shipping (1999), Ugland Nordic Shipping (2001) and the Statoil-owned Navion (2001), some headquarter functions were moved to Canada. However, many headquarter functions were kept in Norway (Grunfeld and Jakobsen 2006). When the Drill & Well equipment

manufacturer Hitec was taken over by the US firm National Oilwell Varco, activities were kept and redeveloped in Norway. The company is now an important part of the NODE cluster in Kristiansand.

However, the very large ratio of foreign to national ownership in the Norwegian supplier industry raises the issue of whether there is a 'trap' in which Norwegian-owned firms must choose between continued Norwegian ownership and internationalization (TEKNA/OLF 2006). One might also ask a number of other questions: What will be the future of the Norwegian oil and gas industry? Will the Norwegian cluster manage to create more Norwegian-owned multinational firms, especially in the supplier industry?

Figure 7-3: Percent of income by ownership portfolio (2002-2008)



Sources: Brønnøysund Register Centre and IRIS/BI

Figure 7-3 shows that Norway has a community of 'serial owners', i.e., owners that hold large stakes in many firms. In the oil and gas industry in 2008, the largest owners of 15% of all firms were also owners of at least two other firms in the industry. Such multiple-firm owners control 70 percent of total income in the industry (the green and red bars combined). In 2008, there were 43 owners who held the largest share in at least 6 oil and gas firms. One important group among these owners is composed of the Norwegian-owned private equity (PE) and venture capitalist (VC) companies, which have sprung up over the last 10-15 years to engage in the business development of this engineering-based industry.

> "A challenge in this region [the Stavanger region] is that start-ups are developed up to a certain level and then bought by global firms. Being acquired by a global firm is not necessarily a bad thing, as it may give many important impulses. But there is still the question of whether the region has had too little focus on business development, i.e., following an idea all the way from design and development and onto the market." Venture capitalist, the Stavanger region

Ferd Private Equity controls two of the largest companies in the Topside sector, Aibel and Beerenberg Corporation. Hitecvision Private Equity, established with the proceeds from the sale of Hitec Industries to National Oilwell Varco, controls the MMO-oriented groups Apply,

Grenland and Stream (part of the former Bjorge group), and the newly formed Subsea Technology Group (a spin-off of a former investment, the Technor Group). The Norwegian investments of the VC firm Energy Ventures include the Drill & Well companies Ziebel and Cubility. While the VC and PE companies are important in nurturing start-ups and restructuring established firms, it is not in their business model to be long-term industrial owners.

In conclusion, foreign ownership is not necessarily bad for either Norwegian employment or technological development. However, foreign ownership of more than 50% of the supplier industry may increase pressure to move or to outsource activities when production on the NCS starts to decrease.

8 Environmental Attractiveness

The Norwegian oil and gas industry is among the world leaders in climate-sensitive, environmentally friendly production. The Norwegian oil and gas industry is, however, committed to further reducing its discharges and emissions (OLF, 2010).

For marine discharges, the most significant confirmed effects originate from earlier discharges of oil-based drilling mud and oily cuttings. Following an initiative to stop these discharges in 1993, discharges of water-based mud and cuttings are now only found in close proximity to oil platforms (OLF, 2010). Today's biggest challenge is related to the discharge of produced water. Produced water is fossil water that follows the oil from the reservoir. Given the focus on this issue, the Norwegian oil and gas industry released ten percent less in 2009 than in 2008, totaling slightly less than 1,500 tons (OLF, 2010). Chemicals are among other potentially environmentally harmful marine discharges. Operating firms have made a considerable effort to replace chemicals that have detrimental environmental properties. This has resulted in a reduction of more than 99 percent of all environmentally hazardous chemicals over the last decade. In 1997, a governmental white paper from 2007 concluded that a zero-added-chemical discharge policy had been fulfilled (OLF, 2010). The NCS has an extensive monitoring program designed to control and improve the environmental impact of the industry on the marine environment. The 2010 program was expanded to include new potential environmental impacts from discharges (OLF, 2010).

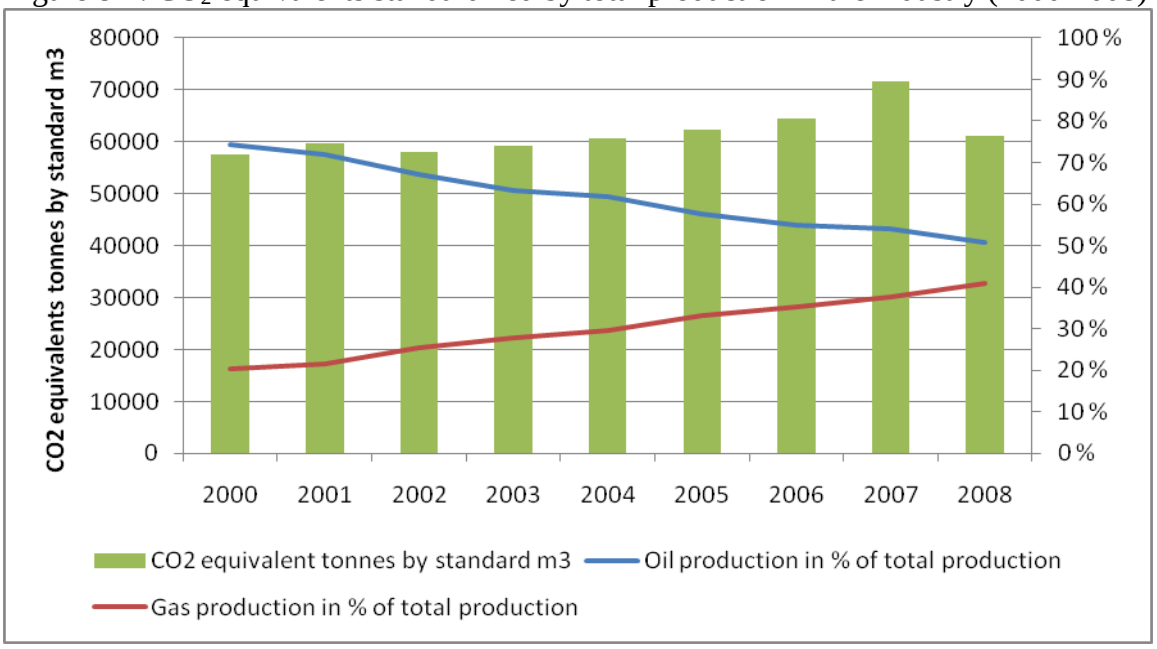
Air emissions are also a priority of the Norwegian oil and gas industry. Emissions of all relevant green house gases from the Norwegian industry were lower than the international averages for oil-producing countries in 2008. Total CO_2 emissions from the NCS were 13.2 million tons in 2009, a decline of 7 percent from 2008. Emissions of NOx (nitrogen oxide) from the oil and gas industry were 49,804 tons in 2009, a reduction of 2.1 percent from 2008 (OLF, 2010). The industry is developing several measures to reduce NO_X and, if those measures are implemented as scheduled, Norway will fulfill its commitments under the Gothenburg protocol (OLF, 2010).

Case: Environmental Projects

Miljø Footprint is a project initiated by Norwegian Offshore and Drilling Engineering (NODE) in order to account for environmental challenges in the oil and gas industry and to give the cluster a collective environmental image. The 'Lighthouse Project', which is supported by the Ministry of Petroleum and Energy, aims to characterize accumulated environmental strains with R&D figures and to develop an environmental standard for the industry that can give it a competitive advantage based on its environmental attractiveness. A pre-project, supported by Innovation Norway, developed a methodology to determine the environmental characteristics of products and services of the oil and gas industry.

The industry's environmental attractiveness is assessed on the basis of standardized CO_2 equivalent levels and R&D investments into CO_2 management. It should be noted that reliable, comparable data on the impact of environmentally related projects is not available. Statistics Norway is attempting to produce such data but the standards as well as reporting systems for all Norwegian sectors have yet to be established.

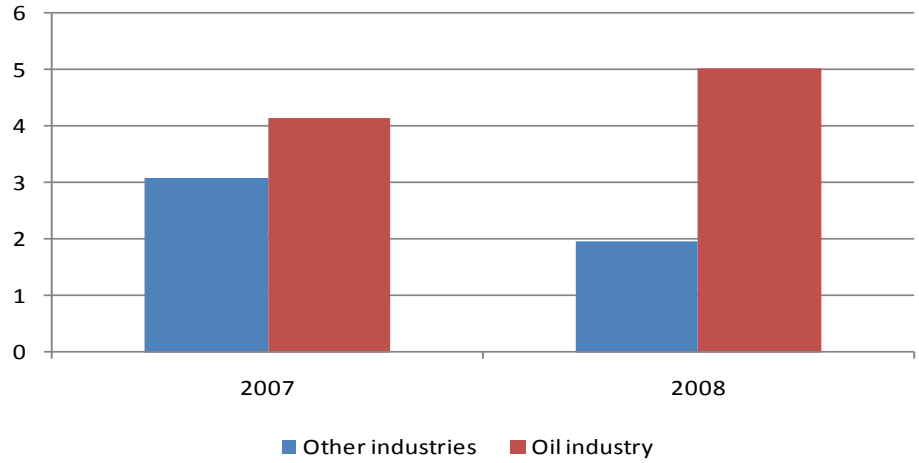
Figure 8-1: CO_2 equivalents standardized by total production in the industry (2000-2008)



Sources: Statistics Norway

With more than 29 percent of emissions of CO_2 equivalents units in Norway attributable to oil and gas activities, the oil and gas industry in Norway is a major contributor to Norwegian-originated emissions.[39] Between 2000 and 2008, emissions of CO_2-equivalent units related to the oil and gas industry increased at an annual average growth rate of 1 percent. In 2008, emissions were significantly reduced, falling by 13 percent. In order to interpret this trend, the emission data was standardized using annual production data for the industry, defined as comprising oil, gas, components and NGL production. As Figure 8-1 illustrates, the increasing trend until 2007 and the decline in 2008 are also observable for standardized emission values. When considering emission trends, the general industry-wide trend of declining oil production and increasing gas production needs to be considered, as it may have indications for improving environmental friendliness.

Figure 8-2: CO_2 management: R&D costs in percent of turnover (2007-2008)



Sources: Statistics Norway and IRIS/BI

[39] http://www.npd.no/Global/Norsk/3%20-%20Publikasjoner/Faktahefter/Fakta2010/Kapittler%20PDF/Fakta_2010_web.pdf

CO_2 management can be considered to be another indicator of the environmental attractiveness of an industry, as it provides insights into the degree to which firms prioritize the handling of environmental concerns in their operations. As Figure 8-2 shows, firms operating in the oil and gas industry invested, on average, four (2007) and five percent (2008) of their turnover in R&D related to the management of CO_2 emissions. Not only is the level of investment increasing for the industry but it is also in contrast to the trend of declining R&D investments in CO_2 management observed in all other industries and the general trend of declining R&D investments in the oil and gas industry. However, more observations are needed to verify the existence of this trend.

In summary, the oil and gas industry is not perceived as a very environmentally friendly industry. The Norwegian oil and gas industry can, however, improve its environmental status through two mechanisms: environmentally friendlier solutions and the continued introduction of standards.

First, many technologies that are more environmentally friendly create a win-win situation: less damage is caused to the environment and more value is extracted. For example, by pumping CO_2 into an oil well, its pressure increases and the rate of oil extraction increases. There are other ongoing initiatives, such as the utilization of microorganisms that also aim to produce win-win solutions. Second, the Norwegian oil and gas industry's environmental standards make it an attractive oil and gas hub. Such standards need to be pushed further. Particularly with respect to the plans to extract oil and gas in the northern areas, the development of higher environmental standards is necessary. Norway has to be at the forefront of the development of more environmentally friendly solutions.[40]

[40] One important aspect here is the safety of the working environment. Norway has been at the forefront of the development of products and routines to ensure the safety of the working environment. However, due to the extensiveness of this report, we do not examine this issue.

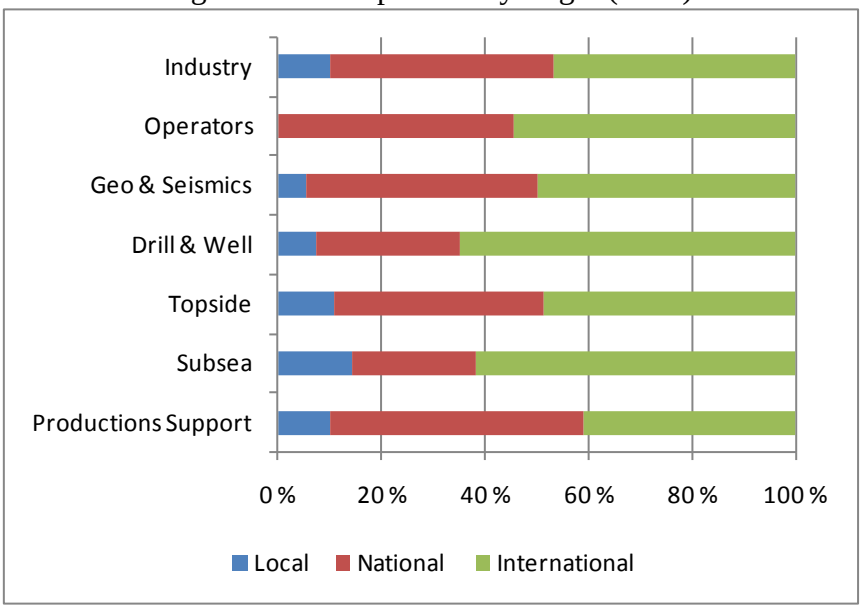
9 Cluster dynamics

The dimensions previously reviewed describe the conditions under which firms can excel. The extent to which firms can utilize those dimensions to their benefit depends greatly on the extent to which they succeed in creating a dynamic environment. Previous literature (Reve and Jakobsen 2001) identifies four upgrading mechanisms by which clustered firms can experience increased innovation and productivity: innovation pressure arising from closeness to demanding customers, technologically leading suppliers and internal competition; critical mass (section 3); knowledge externalities, mainly in the form of labor mobility and strong business linkages; and transaction cost reductions through the establishment of long-term relations. Dynamism is, therefore, a function of competitive and cooperative linkages, the degree of intra-industry labor mobility, which proxies for the extent of knowledge spillovers, and the degree of overlap between various industries. These linkages are examined in this section.

9.1 Competitive linkages

The Norwegian oil and gas industry has evolved from a state of non-existence in the late 1960s into an internationally competitive industry with strong local competitive environments in almost all parts of the value chain. On the industry level, firms primarily face the toughest competition for customers from international firms. This reflects the global nature of the industry, as well as its maturity and competitiveness. Only 10 percent of all firms state that locally originating competition for customers is the biggest source of competitive rivalry (Figure 9-1). The technology-based suppliers, especially those in the Drill & Well and Subsea sectors, face the toughest competition from international competitors.

Figure 9-1: Competition by origin (2010)



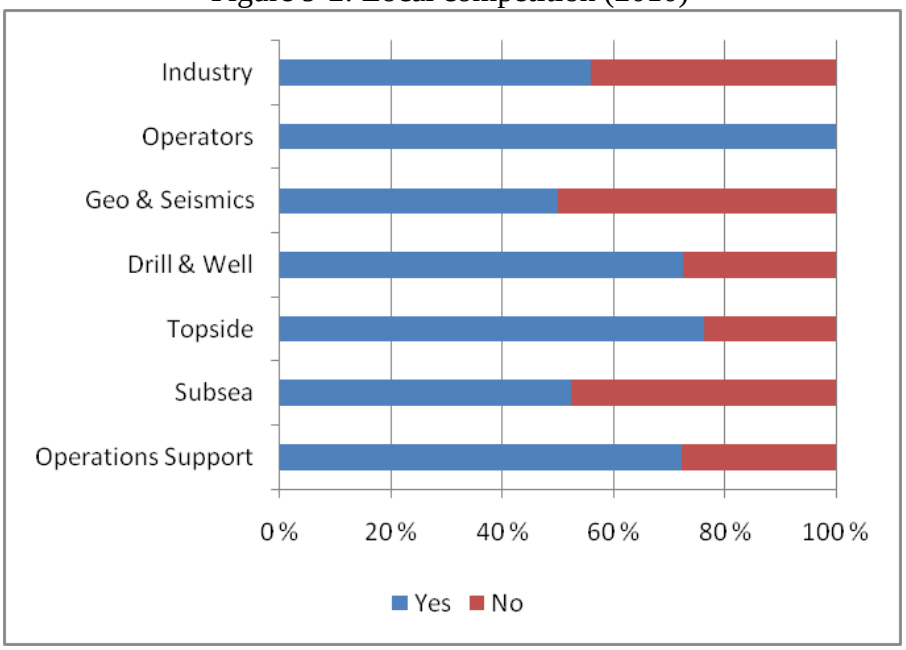
Source: IRIS/BI Survey

Is the strong international competition complemented by a strong competitive environment at home? The degree of local competition has been theorized to drive firms to excel (Porter 1990; Burt 1992). Repeatedly, competing firms that locate in the same vicinity have been observed to have an incentive to remain ‘on top of things’ by continuously innovating and seeking new technologies and customers. Parts of the oil and gas industry have evolved in this

direction. Within the Subsea sector in Kongsberg, we find both FMC and Kongsberg Maritime, while within the Drill & Well sector we find both Aker MH AS and National Oil Well Varco Norway AS, as well as many smaller firms. The majority of firms (56 percent) report having at least one direct competitor located within a one-hour drive (Figure 9-2).

However, the distribution is not homogeneous across sectors. While all Operators report a direct competitor in the immediate vicinity of their own location, only half of the technology-heavy firms in the Subsea and Geo & Seismics sectors report the existence of local, direct competitors. The existence of local competitors is crucial to the development of a dedicated business community that thrives over time.

Figure 9-2: Local competition (2010)



Sources: IRIS/BI Survey

For example, the Subsea sector is geographically distributed across three major regions: Hordaland, Buskerud and Rogaland. This distribution weakens the individual firm's ability to recognize trends, local knowledge spillovers and incentives for continual renewal. The same pattern is visible in the Geo & Seismics sector. The sector is not co-located in one area but is almost equally split among Oslo/Akershus, Rogaland and Hordaland.

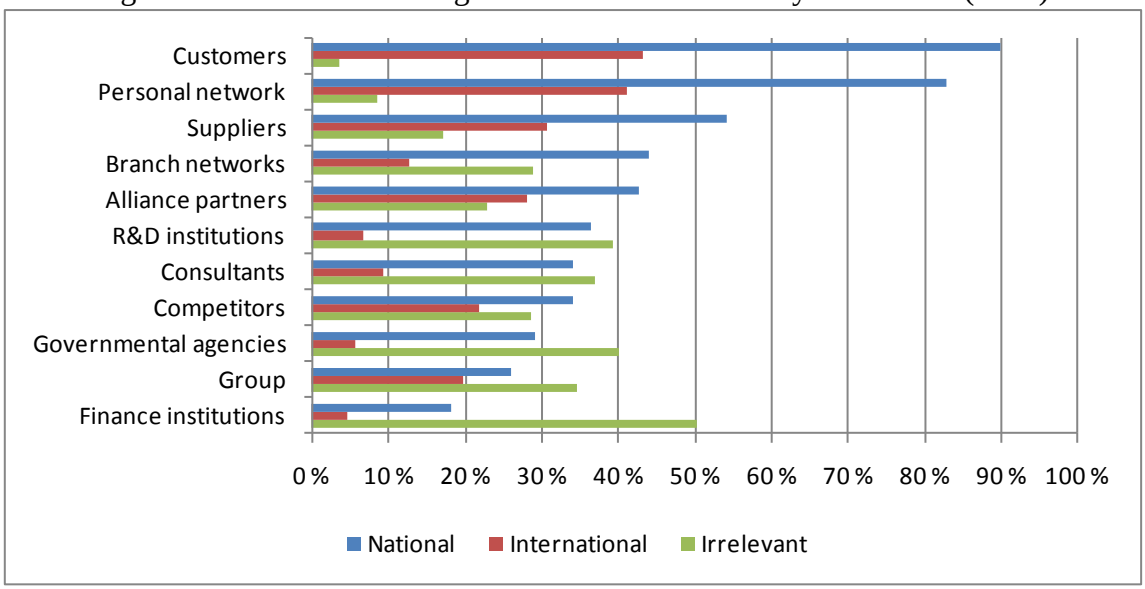
9.2 Collaborative linkages

Innovations happen less frequently in isolation, and R&D is increasingly more interconnected and globalized. Innovative linkages across firm and country boundaries allow for higher returns from the sharing of cross-boundary knowledge, the joining of complementary resources and the transferring of effective governance of work and innovation processes (Dyer and Singh 1998). Given the increasing globalization of economic activities, cross-border linkages are of increasing importance (OECD 2010). Norway as a whole underperforms in this regard. Only 5 percent of firms report that they are involved in international collaboration on innovation. By comparison, 17 percent of Finnish and 8 percent of Danish firms report that they are involved in international collaboration on innovation.

For the industry as a whole, relations with certain actors are more significant than relationships with others in the development of new ideas, processes or products (Figure 9-3).

Financial institutions are largely irrelevant, whereas relationships with customers, suppliers and personal networks on all geographic levels are of key importance. Alliances, competitors and branch network organizations also play important roles in facilitating innovation activity.

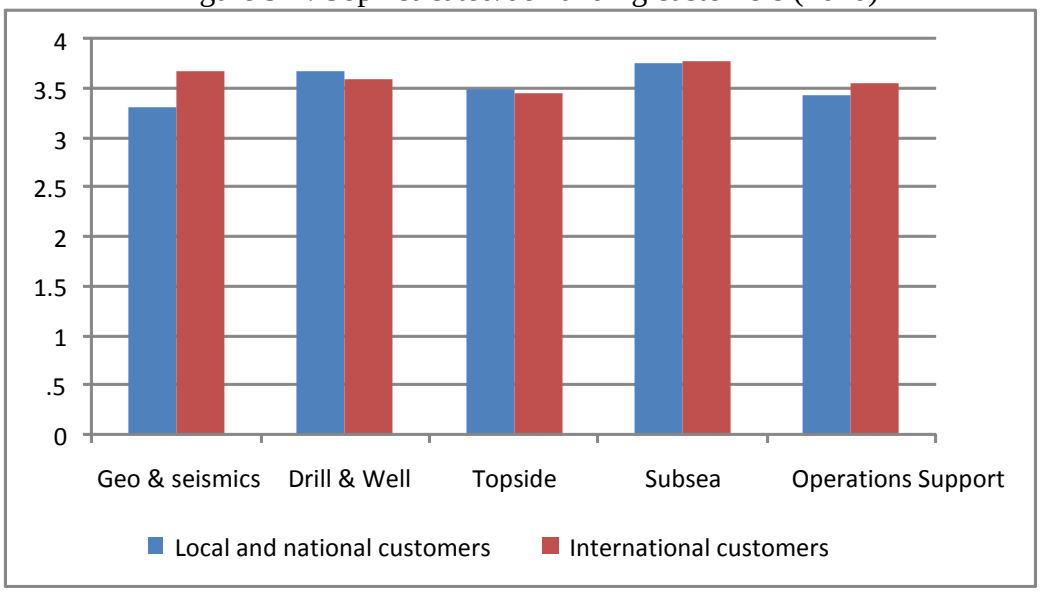
Figure 9-3: Innovative linkages across firm and country boundaries (2010)



Sources: IRIS/BI Survey

Customers are the most important source of new ideas, processes or products in the oil and gas industry. This is further supported by the level of customer sophistication. On a scale from 1 to 4, the main picture is that the sophistication is generally very close to 4 (Figure 9-4), although there are some differences among sectors, and between local/national and international customers, especially in the Geo & Seismics sector. The more demanding the customer group, the more supplying firms have an incentive to innovate to meet customer demands (Porter 1990).

Figure 9-4: Sophisticated/demanding customers (2010)

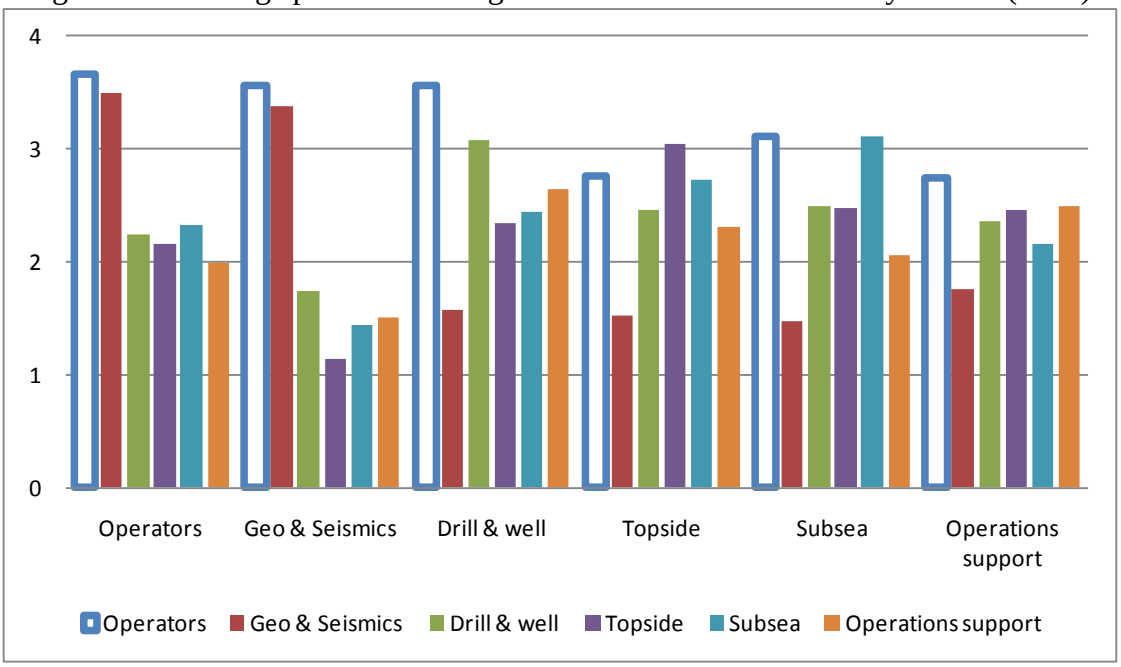


Sources: IRIS/BI Survey

Although the industry as a whole views customers as being of great importance, Operators deviate from this trend. This reflects the varying roles of actors within the industry and the fact that Operators are the main customers for all of the other sectors. As customers, Operators have an important role to play in the development of new ideas, processes and products for all other actors. They play a unique role in the industry in that they perform activities differently from the rest of the industry players. As industry leaders, Operators identify future opportunities for competitive leadership and therefore request innovative solutions from their suppliers. The position of Operators as knowledgeable and sophisticated customers is important to all other sectors in the industry and, in this regard, they have a significant role to play in innovation development in the oil and gas industry.

Operators' customers are usually the end users or distributors of products. As they are generally consuming a standardized product, there is less that these end users can contribute to Operators' innovation ideas. This is reflected in our finding that customers of Operators are largely irrelevant in this respect. Firms in the rest of the sectors rate national customers as the most important source of innovation. This may indicate the importance of sophisticated local and national Norwegian customers, particularly customers requiring engineering-dependent services and products.

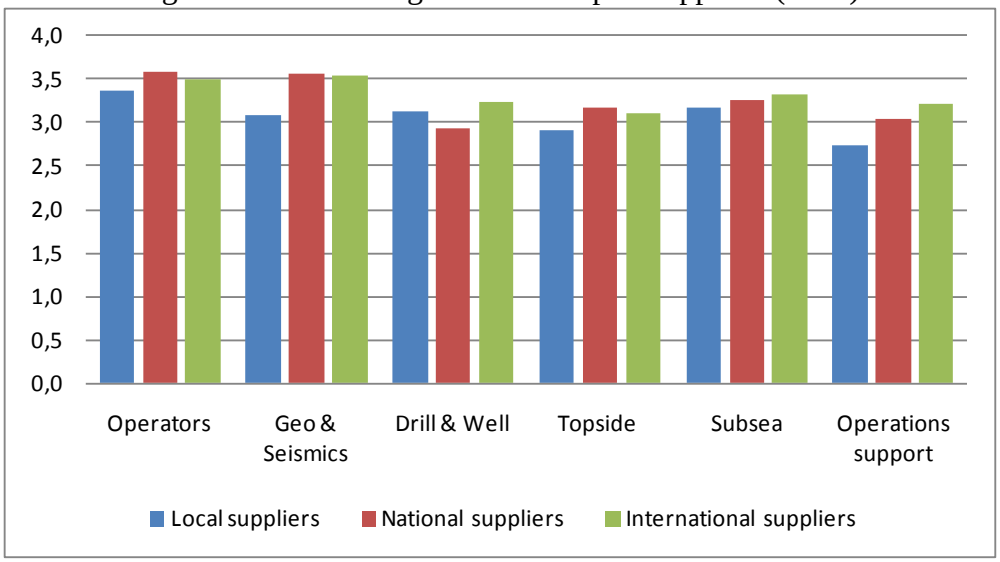
Figure 9-5: Average perceived strength of relations to other industry sectors (2010)



Sources: IRIS/BI Survey

The importance of Operators is evident in Figure 9-5, which shows the perceived strength of the relationships between the different sectors of the industry with 1 being no relation and 4 being a strong relation. The figure shows that besides intra-sector relations (Topside firms having relations with other Topside firms, etc.), the only really important relation for the suppliers is their relation with Operators. The figure also shows that the sectors with the strongest relations to Operators are Geo & Seismics, and Drill & Well.

Figure 9-6: Technological leadership of suppliers (2010)



Sources: IRIS/BI Survey

The second most important actors sector, with the exception of the general category of personal networks, is suppliers. With the clear exception of Operations Support, all sectors perceive their suppliers as technological leaders. The difference between local, national and international suppliers is marginal, which indicates that the sophistication of the supply sector in Norway does not fall short of international technological leadership (Figure 9-6). The technology-based suppliers perceive their own suppliers as technological leaders almost on par with their foreign suppliers. In Operations Support, local and national suppliers are perceived to be less technologically advanced than international suppliers. In this sector, which is expected to grow in the near future, there is significant room for improvement in terms of getting the suppliers' suppliers to excel as well (Håkansson and Snehota 1995).

Case: Cooperation in innovation – IOSS/FMC/Aker/Oceaneering

A major challenge connected to subsea field development is that the costs of well interventions are three to five times higher than for traditional topside wells. Traditional wells may be intervened directly from the surface installations. For intervention of subsea wells, rigs must be towed in place and anchored, and massive risers must be put into place on the seabed. In the late 1990s, PGS tried to construct specially designed intervention vessels to make vessel-based intervention possible. However, the project failed.

In the early 2000s, FMC Technologies developed a technology to use cables instead of risers between surface and seabed together with a lubrificator (valve system) to be put onto the "Christmas tree" to facilitate intervention. At the same time, three former employees of PGS Intervention tried, in vain, to raise capital for another attempt with a specially designed intervention vessel. In the end, this group was able to team up with Morten Ulstein and his company, Island Offshore. Island Offshore established a partnership with FMC, which needed a platform for its technology. Aker Well Services was included in the alliance as a wireline operator.

Case: Cooperation in innovation – IOSS/FMC/Aker/Oceaneering (continued)

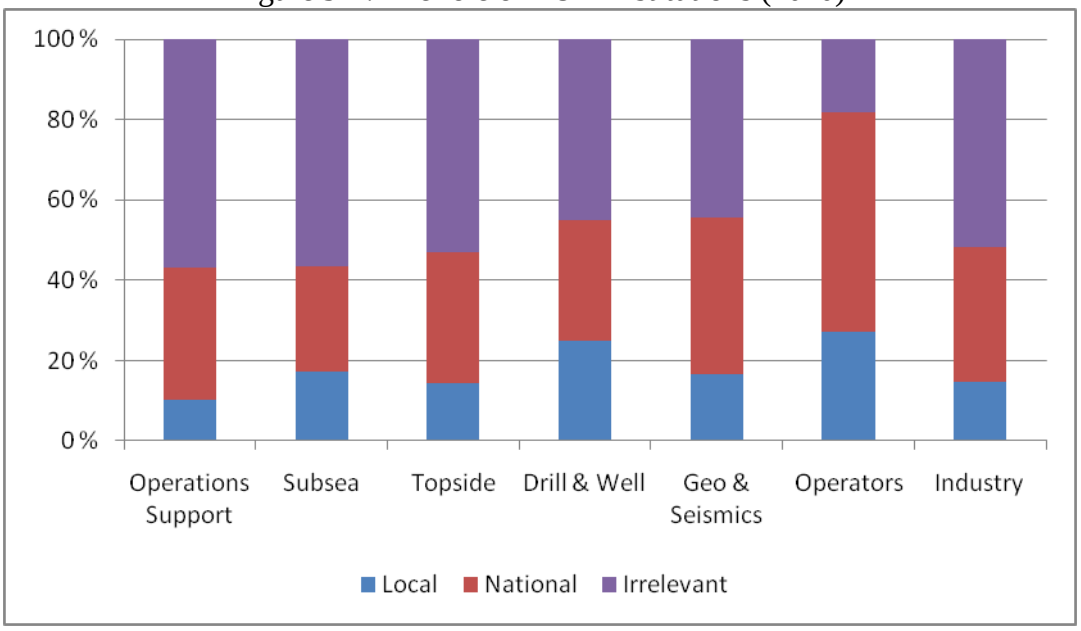
As the alliance failed to land any contracts with operators, Island Offshore decided to build the first vessel (Island Frontier) on pure speculation. Island Offshore Subsea (IOSS), a partially owned subsidiary of Island Offshore, was set up to administer vessel operations and the intervention services.

Island Offshore's gamble paid off, first with contracts in the UK sector and then with numerous contracts on the NCS. At present, IOSS has three intervention vessels and two more are under construction. The alliance (IOSS, FMC and Aker Well Services) has improved upon FMC's original technology and a second-generation lubrificator was brought into use in 2009. According to IOSS, one of the main reasons for its success is its ability to bridge the gap between two segments of the oil industry that hitherto had been worlds apart: drill & well and maritime services. IOSS is considering extending its competency into reservoir modeling, which may be useful for further development of its services.

9.2.1 Collaborations with R&D institutes

In order to better understand these trends, we compare industry results with sector-specific results. We first look at the role of R&D institutions, as approximately half of the industry players rate them as irrelevant (Figure 9-7). International R&D institutions have been removed from this analysis, as they were not reported to be of significance to any sector. The industry trend regarding the role of R&D institutions is clear in all sectors, i.e., R&D institutions are largely considered to be irrelevant and only national R&D institutions are viewed as having a notable role to play. However, this should not lead to the conclusion that these institutions are irrelevant for several reasons. First, the oil and gas industry is very diverse and firms, especially those in the less-advanced service provision activities, gain little from relations with R&D institutions. Second, the lead time from academic research to actual innovation may be so long that many companies do not count it as an important factor in innovation. For example, the basic research for the current subsea boom started in the early 1980s (Noreng 2004). Third, almost 50 percent of firms report that nationally based R&D institutions play a role in their innovation.

Figure 9-7: The role of R&D institutions (2010)



Sources: IRIS/BI Survey

The only clear exception to this trend is evident in the Operators sector, where R&D plays a much more important role, particularly on the national level. The relevance and importance of R&D to this sector is reflected in the fact that Operators outsource the vast majority of R&D activities. Rather than undertaking R&D themselves, these companies appreciate the need for expert help if they are to remain competitive and technologically advanced. As discussed in section 6, Operators utilize cooperative R&D relationships and outsource R&D projects to a large extent.

When discussing the role of R&D institutions, one should not only consider them as a group of researchers developing brilliant ideas that are then seized upon to create successful firms. According to one study (Karlsen *et al.* 2002), one important role of R&D institutions is to provide the industry with laboratories and test facilities. IRIS in Stavanger and SINTEF in Trondheim have full-scale test facilities for Drill & Well technologies, and CCB-base at Ågotnes has similar facilities for maritime and subsea technologies. In addition, SINTEF, the Institute for Energy Technology (IFE) and CMR have advanced laboratories. With the expected decline in national oil and gas operations, the importance of such facilities and, hence, of R&D institutions is likely to increase.

> "It is a pity that Stavanger municipality decided to close down the oil and gas facilities at Jåttåvågen. This used to be one of the country's best test sites for subsea technology."
> CEO, large oil and gas supplier

Case: Dedicated Collaboration – Norwegian Centers of Expertise

Three publicly owned institutions geared towards industrial development (The Research Council of Norway, SIVA and Innovation Norway) have established a program to assist in the development of strong regional clusters. At present, 12 regional clusters have been designated as a Norwegian Centers of Expertise (NCE), while 17 others are using the related Arena program to help qualify as an NCE in the future.

Of the 17 Arena projects, 3 are geared towards the oil and gas industry: the Centre for Smart and Safe Wells and Integrated Operations, both in Stavanger, and Offshore Support Vessels in Southern Hordaland and Northern Rogaland. Of the 12 NCEs, 2 are geared specifically towards the oil and gas industry: NCE Subsea in Bergen and NCE NODE (Norwegian Offshore & Drilling Engineering) in Kristiansand.

Hordaland is a strong shipping region and is home to Norway's largest naval base, Haakonsvern. In recent years, it has also developed a strong regional subsea cluster consisting of suppliers and Statoil's departments for subsea activities. The goal of NCE Subsea is to become a world leader in subsea technology with a focus on technology supply, operations and maintenance/modification. The cluster facilitator works with technology development, business cooperation, internationalization, recruitment/ competence and cluster communication/branding.

In the 1990s, the southern part of Norway was not seen as an important part of the Norwegian oil and gas industry. The region is now home to about 50 firms engaged in the design and fabrication of equipment related to Drill & Well, with the two largest firms being National Oilwell Varco (2,000 employees) and Aker Maritime Hydraulics (1,000 employees). In 2005, the firms engaged in a project to strengthen the cluster and in 2009 the region was awarded status as a National Centre of Expertise (NCE). The cluster has experienced enormous growth – from 2000 to 2007, its combined sales grew sevenfold (Konkraft 2008). In 2007, the amount of foreign sales in the cluster was 85 percent (ECON 2010), making it one of the most internationalized clusters in the Norwegian oil and gas industry.

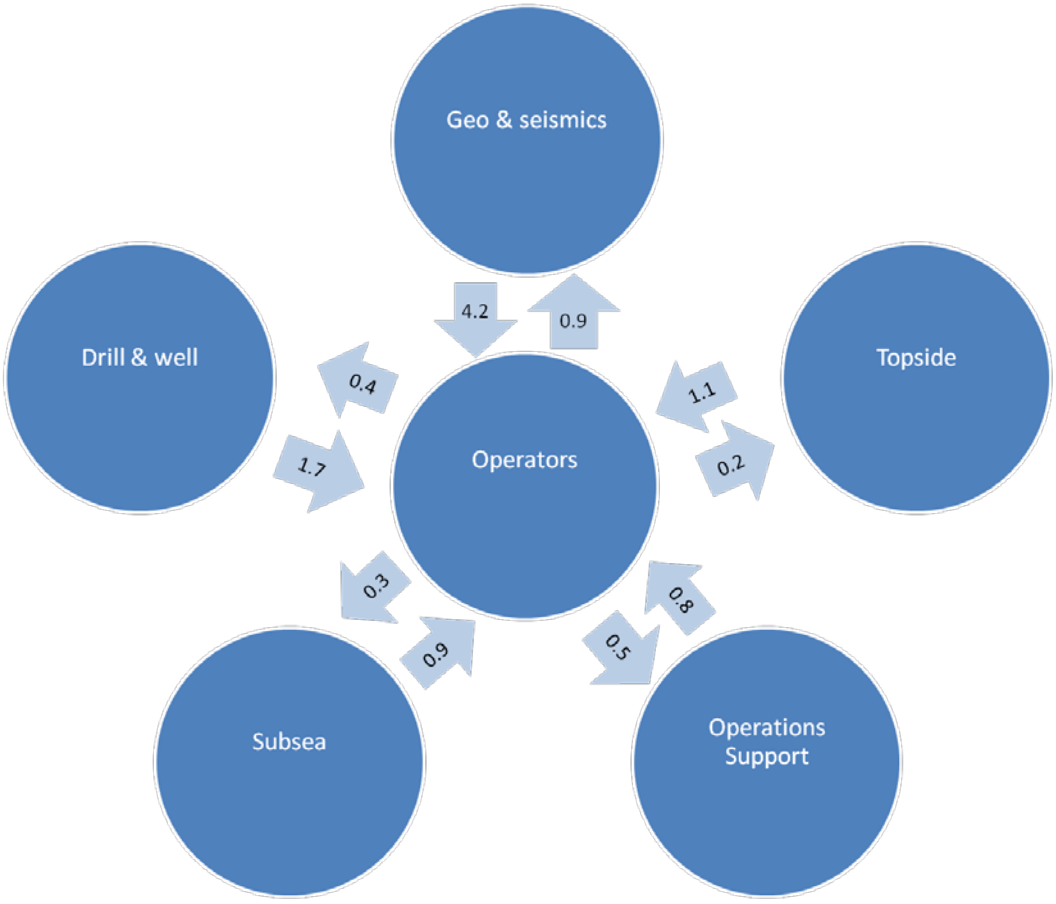
9.3 Labor Dynamics

Another method by which industry dynamics can be created is through the labor market. Spillover effects have been identified as one of the three major mechanisms by which cluster advantages materialize (Marshall 1920; Jaffe *et al.* 1993; Almeida and Kogut 1999). Spillovers occur in labor markets through transfers of employees across firm boundaries. The labor dynamics within the different sectors of the oil and gas industry vary greatly. Figure 9-8 presents the Balassa index of labor mobility between Operators and all other sectors. A value of one signifies that the expected number of workers moved from one sector to another in accordance with the relative size of the sector in the oil and gas industry. A value of less than one signifies that fewer workers moved than expected, and a value of more than one signifies

that more than the expected number of workers changed sector. Operators do not contribute to the other sectors according to their expected size, as they play a role of competence receivers rather than competence providers. Employees working for Operators are less likely to move to any of the other sectors, as expected.

However, employees working in the other activities are highly likely to take a job with Operators (and not move thereafter). This attractiveness measure controls for the size of the sectors and, hence, it is not a function of sector size. Operators receive a disproportionately high number of employees from all of the other sectors. The highest over-representation of inter-sector knowledge transfer to Operators is evident in the flow from Geo & Seismics, which sends more than 4.2 times the amount of workers that are expected to move, and in the flow from Drill & Well, which sends 1.7 times as many workers as expected. Topside, Subsea and Operations Support provide roughly the expected proportion of employees.

Figure 9-8: Inter-sector labor movement (2008)



Sources: Statistics Norway – Employment Register and IRIS/BI

Table 9-1 presents the Balassa index for the relationships among the technology-based supplying sectors for all educational levels in 2008. The most significant transfers are marked in bold. From the table, we can observe that the technical service providers are embedded in a relatively closed and cohesive network. The transfer of employees between these sectors is much higher than expected. The same pattern emerges when the Balassa index is calculated for previous years.

Table 9-1: Labor mobility among sectors (2008)

To: \ From:	Geo & seismics	Drill & well	Subsea
Geo & Seismics		1.2	**1.9**
Drill & well	**1.5**		**1.6**
Subsea	**2.1**	**2.0**	

Sources: Statistics Norway – Employment Register and IRIS/BI

When investigating the same measure of knowledge transfer for higher education only, the same pattern emerges, albeit with slight moderations to the magnitude of labor flows (Table 9-2). One important aspect to note is the large decrease in the Subsea sector as a knowledge provider and the increase of Subsea as a knowledge receiver when only higher education is considered. This signifies that Subsea firms act as a magnet for the highly educated workforce currently employed in Geo & Seismics, Drill & Well and Topside. Notwithstanding the current opportunities within Subsea, the sector is attractive to all other sectors apart from Operators, where employees have the lowest incentive to move to this growing sector.

Table 9-2: Labor mobility among sectors for employees with university degrees (2008)

To: \ From:	Operators	Geo & Seismics	Drill & well	Topside	Subsea	Operations Support
Operators		**3.5**	**1.9**	1.2	0.9	1.0
Geo & Seismics	0.8		**1.6**	0.7	1.2	1.4
Drill & well	0.6	**2.1**		1.3	1.1	**1.5**
Topside	0.3	0.6	1.3		1.2	**3.4**
Subsea	0.3	**2.0**	**1.5**	**1.5**		1.4
Operations Support	0.6	0.7	1.3	**1.7**	**1.6**	

Sources: Statistics Norway – Employment Register and IRIS/BI

9.4 Overlapping Networks

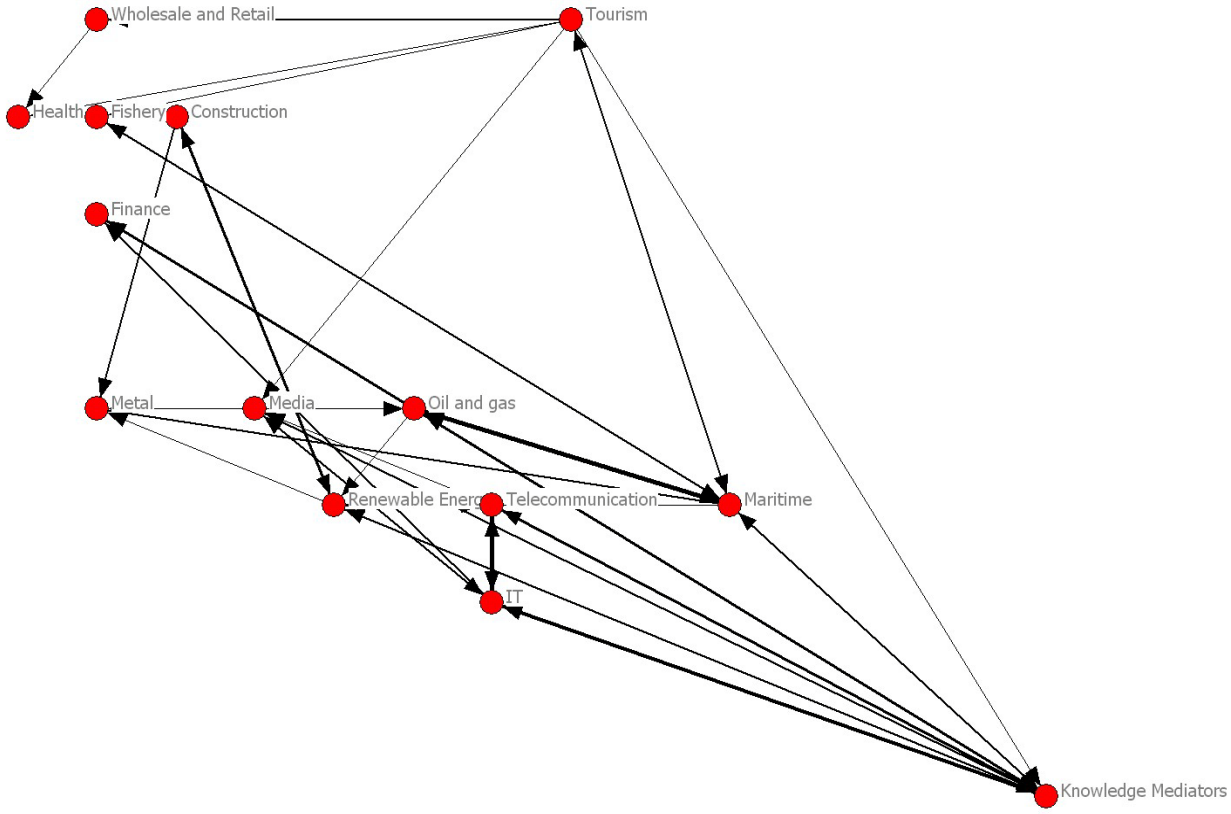
Clusters thrive in the presence of related clusters in the economy from which they can draw upon (Porter 1990; Porter 1998). Is the oil industry a standalone industry, or does it have related clusters and, hence, complementary sources of competences and ideas to utilize in its operations? Figure 9-9 presents an overview of labor mobility among industries in Norway during 2008. A similar picture emerges when the data for 2006 or 2007 is analyzed. The lines in the figure indicate an over-representation of labor mobility between any two industries. The thickness of lines represents the strength of the over-representation. The vertical axis represents the degree to which an industry sends labor to other industries, while the horizontal axis represents the degree to which an industry receives labor from other industries.

The oil industry is an established industry that enjoys a strong two-way connection with the maritime industry. This relationship has been mutually beneficial to both industries over the last 40 years of offshore operations. The oil industry also disproportionally receives employees from the metal processing industry and from advanced-knowledge mediators like DNV, technology consultancies, and dedicated law firms. With regards to the inter-cluster labor linkages for the highly educated workforce, the picture remains unchanged. In fact, the

link to the metal industry becomes even stronger when only employees with university education are included. All other linkages remain as important.

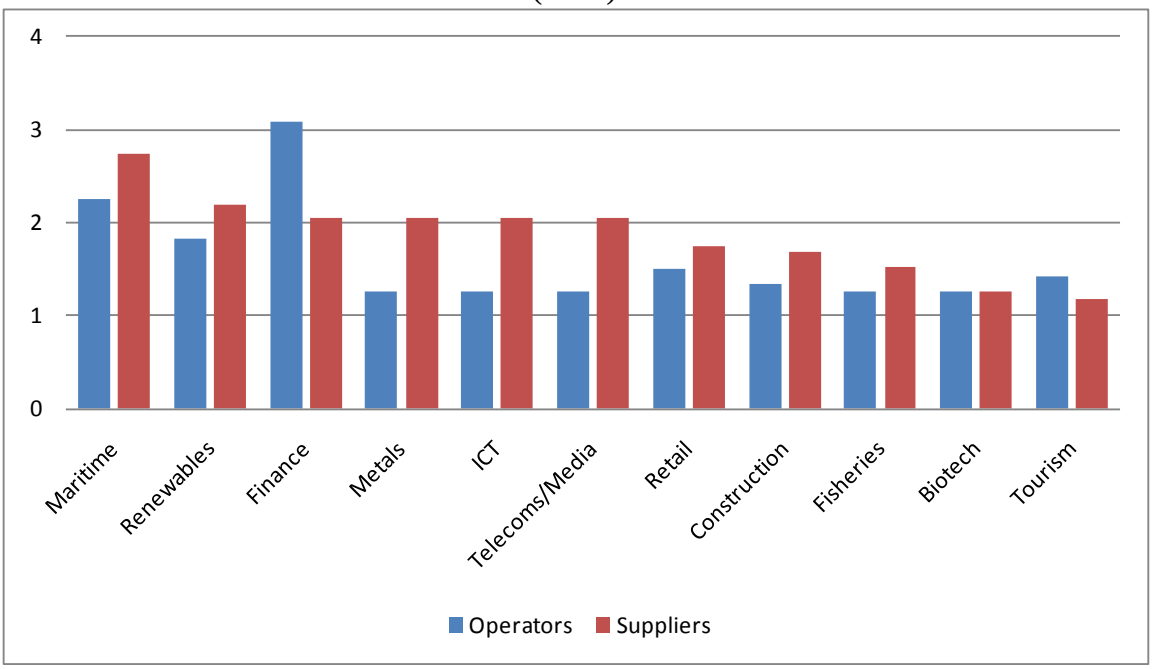
Along with its primarily inter-cluster relation with the maritime industry, the oil and gas industry is weaving a tight national network of relations that encompasses metal processing firms, especially Topside and Subsea-related suppliers, and advanced knowledge-intensive firms that have specialized in providing oil-related services. Future studies should examine the extent to which these related industries have managed to internationalize their operations (mostly services) in a fashion similar to the advanced maritime services industry. It should be noted that any decline in the sectors' activities will have dramatic effects on these two industries as well.

Figure 9-9: Overlapping networks (2008)



Sources: Statistics Norway – Employment Register and IRIS/BI

Figure 9-10: Strength of relations between Operators and Suppliers and other industries (2010)



Source: IRIS/BI Survey

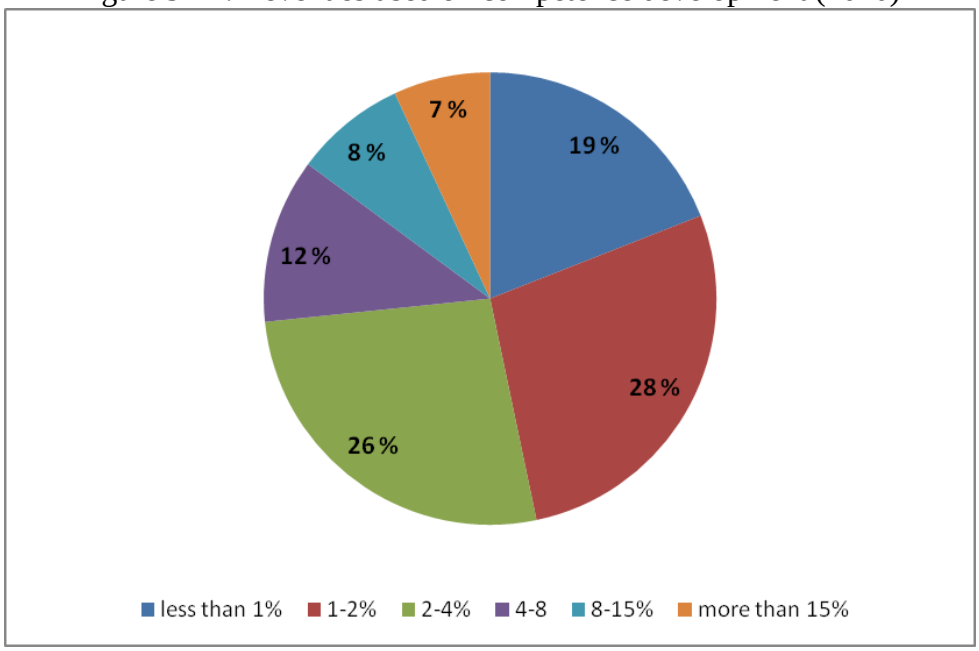
Figure 9-10 provides a picture similar to that seen for the labor networks. Survey respondents reported the strength of the relations that their firms have with other industries (1 = No relation; 4 = Strong relation). The only industries with which suppliers have above-average relations (i.e., a reported strength above 2) are the maritime industry and renewable energy. Operators report a very strong relation with Finance (3) but this relationship is considerably weaker among suppliers (2). The suppliers have average (strength = 2) relationships with the metals, ICT and telecoms/media industries, and hardly any relations with other industries.

9.5 Indirect linkages: Competence development

Firms can supplement investments made by educational institutions, individual employment choices and spillovers from already acquired industrial knowledge by investing in employee competence development (Figure 9-11). Investment in employee competences is examined here because it is a semi-public good. There is no guarantee that an employee will remain with the firm and, hence, the proceeds of investments in competences may be captured by other firms.

47 percent of firms invest less than 2 percent of turnover on developing employee competences. This number is identical to the investments made by the health industry, a knowledge-intensive industry. We find that many oil and gas firms (26 percent) invest between 2 and 4 percent of turnover on competence development, which is higher than in the health industry. On the high end, seven percent of oil and gas firms invest more than 15 percent of turnover on developing competences, while 13 percent of the health industry firms do the same. When the nature of the oil and gas industry and its partial reliance on labor-intensive activities are taken into account, this indicates high investments in competence development.

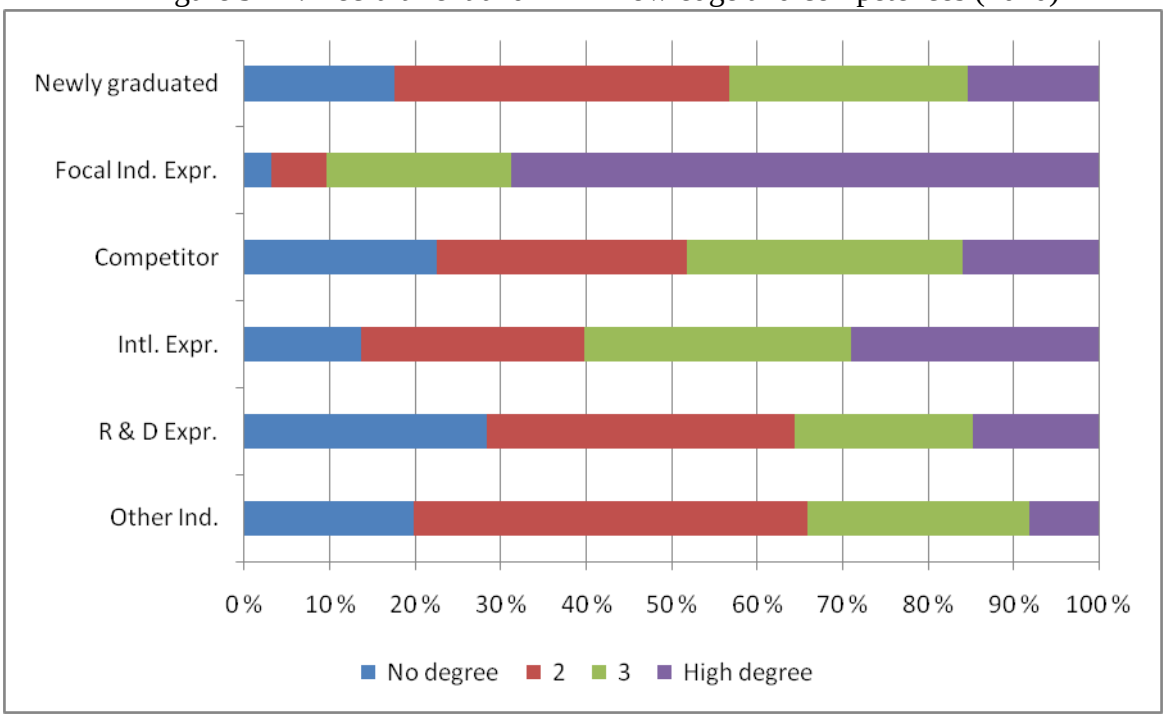
Figure 9-11: Revenues used on competence development (2010)



Sources: IRIS/BI Survey

The recruitment of employees with focal industry experience is regarded by almost 70 percent of firms surveyed as contributing a high degree of knowledge to the firm. The second most important recruitment channel for knowledge is found in workers with international experience, which 60 percent of the respondents regard as contributing an average or high degree of knowledge, and almost 30 percent regard to be contributing a high degree of knowledge (Figure 9-12).

Figure 9-12: Recruitment and firm knowledge and competences (2010)



Sources: IRIS/BI Survey

When the sectors are examined individually, one trend is visible and is in line with the flow data on labor movement. Operators place significantly more emphasis on focal industry training, with almost 85 percent regarding this as important to a high degree. This follows the logic of Operators being receivers of knowledge. At the same time, 50 percent of Operators regard other industries as having no degree of importance for the strengthening of firm knowledge and competences, and roughly 35 percent regard their importance as below average. The specialized service providers in Geo & Seismics and Drill & Well also place little importance on other industries as providers of knowledge. In Geo & Seismics, 60 percent of firms answer that other industries have no degree of importance to their knowledge development in recruiting, and another 20 percent regard their importance as below average. In Drill & Well, roughly 90 percent of firms regard other industries as having no degree or a below average degree of importance for their development of knowledge and competences through recruitment.

In summary, the oil industry makes considerable investments in employee competence, which is in line with what would be expected for a more knowledge-intensive industry. Recruitment is primarily sought among individuals with industry experience and, on a secondary level, among individuals with international experience.

9.6 Cluster dynamics: Conclusions

The Norwegian oil and gas industry is internationally competitive with strong local competitive environments in almost all parts of the value chain. The industry's innovation system is based on a high degree of collaboration between suppliers of technology solutions and operators. In addition, well-developed collaborations between sophisticated customers and advanced suppliers are important for both innovation and internationalization. In this regard, the advancement of the suppliers of the industry's supplier firms should be a priority. If national oil and gas operations decline, the importance of test facilities and, hence, of R&D institutions, is likely to increase.

The system of intra-industry labor mobility is both Operator-centric and technology heavy cohesive grouping. It is Operator-centric because Operators are the preferred employment destination in this system. They receive disproportionate amounts of labor from other sectors within the oil industry but provide very little labor to these sectors in return. The system is technology heavy cohesive grouping because there are disproportionately large and reciprocal labor movements, especially among Geo & Seismics, Drill & Well and Subsea.

Clusters thrive in the presence of related clusters. The oil industry has woven a tight network of relations, which is supported by the transfer of labor to and from the maritime and metal-processing industries, as well as to and from advanced knowledge mediators like DNV and technology consulting firms. A vibrant community of businesses contributes directly to the success of the oil and gas industry.

Oil industry firms invest in competence development as much as firms in the health industry, although the latter is considered to be a much more knowledge-intensive industry. If we combine the intra-industry labor mobility findings with the industry's focus on the recruitment of people with industry experience, a reduction in the activity level in the supply industry will also affect Operators, as competent labor gains experience in the supply industry before moving to Operators.

10 Summary of findings, implications and recommendations

In this concluding chapter, we summarize the major findings of the study and provide recommendations for business strategy and public policy.

10.1 Summary of findings

This report focuses on the current status and emerging trends within the seven dimensions of the Norwegian oil and gas industry as a global knowledge hub: cluster attractiveness, educational attractiveness, talent attractiveness, R&D and innovation attractiveness, ownership attractiveness, environmental attractiveness and cluster dynamics. The main results are summarized below.

10.1.1 The Norwegian oil and gas industry – past, present and future

Although it started from modest beginnings as a producer of oil and gas in 1971, Norway had become the worlds' 13th largest producer of oil and its fourth-largest producer of natural gas in 2009. The Norwegian oil and gas industry was built upon established Norwegian competences in mining (geophysics), maritime operations and maritime construction (yards), with invaluable inputs from foreign operators and suppliers. At present, the industry is a complete cluster of 136,000 employees divided into several sectors: Operators (22,000), Geo & Seismics (4,000), Drill & Well (20,000), Topside (43,000), Subsea (13,000) and Operations Support (34,000). The value creation from operators and suppliers combined represents one-third of total Norwegian GDP (2008).

Employment in the oil and gas industry has been steadily increasing but has fluctuated with the level of investments. Currently, the activity level on the NCS is high. Investments on the Norwegian shelf are at an all-time high, with planned investments for 2011 at NOK 135 billion (Norwegian Petroleum Directorate). Investments in new offshore installations are decreasing, while investments in drilling and well and in the maintenance and modification of existing installations are increasing. While the rate of discovery (discoveries per exploration well) has increased, the average size of discoveries has declined. Production on the NCS peaked in the mid-2000s and is now expected to gradually decline. This development has led to a focus on improved recovery, and on the possibility of opening new areas for oil and gas production.

Future employment in the Norwegian oil and gas industry will depend on the level of activity on the NCS, the introduction of labor-saving technologies and the effects of increased internationalization. It is, however, possible that employment is at or near peak levels.

> "The Norwegian oil and gas industry will last another 50-100 years or more, but employment may very well have leveled out. There are, though, some conflicting trends. First, the increased focus on rationalization, e.g., through integrated operations (IO) and the abandonment of older fields, will tend to reduce employment. Second, the need for more work related to maintenance and modification (MMO), increased recovery efforts and decommissioning will tend to increase employment. Third, the growing internationalization of the supplier industry will lead to higher sales and may even lead to higher employment in Norway." Norwegian Oil Industry Association (OLF)

10.1.2 Cluster attractiveness

The Norwegian oil and gas industry is viewed as having a very high level of competence compared to other oil and gas hubs (Houston and the UK). Norwegian-based firms cover all technical parts of the value chain and Norway has become the global hub for many of these activities. There is a healthy distribution of companies of different sizes, including large companies and start-ups. The last ten years have seen an improvement in terms of both access to capital and quality of financial services provided. However, for the larger companies, there is still a wide spread dependency on international finance institutions.

All sectors of the industry report strong earnings for personnel (measured in terms of costs of personnel per employee) and for capital (measured in terms of profit margins). Costs of personnel are the highest in Geo & Seismics and Drill & Well, and the lowest in Operations Support and Topside. Profit margins are the highest among Operators, most probably as a result of the petroleum rent's role in capital yield. Among suppliers, profit margins are highest in Geo & Seismics, Drill & Well and Operations Support, and lowest in Topside.

Value creation per employee[41] ranges from NOK 1.2 million for suppliers to NOK 6.5 million for operators. In comparison, value creation per employee in the Tourism industry is NOK 0.4 million, while it is NOK 1.4 million in the Maritime sector, which includes parts of the oil and gas industry (Knowledge-Based Norway projects of Tourism (2010) and Maritime (2011).

The supplier industry has managed internationalization successfully. It is estimated that 30 percent of sales in Norway are exported. Exports from oil and gas suppliers, therefore, represent 15 percent of total Norwegian exports when sales of oil and gas are excluded. The export value is complemented by capital income from repatriated profits from foreign subsidiaries.

Two factors force Norwegian-based companies to establish local subsidiaries if they want to conduct business in promising offshore provinces, such as Brazil or West Africa. The first is national demands for 'local content', which are the same forces that helped shape the Norwegian-based supplier industry. The second is the economic fact that foreign operations cannot be competitive if they are based solely on Norwegian expatriates and Norwegian-made materials.

A division of the industry into regional subclusters highlights significant regional variations in terms of total employment and in terms of personnel with a higher education (engineers and economists). Of the mainland counties, the bulk of employment (just below 50%) is located in Rogaland and Hordaland, followed by Oslo/Akershus, Møre and Romsdal, Agder, Sør-Trøndelag and Buskerud. The subclusters in Oslo/Akershus (all sectors excluding Drill & Well) and in Buskerud (Subsea) have significantly higher shares of engineers/economists than the other regional clusters. However, the absolute numbers of engineers/economists in the Drill & Well cluster in Rogaland and the Topside cluster in Rogaland/Hordaland are significant.

10.1.3 Educational attractiveness

Educational programs that are related to the oil and gas industry have grown in popularity in both absolute and relative terms on both the Bachelor and Master levels. However, programs dedicated to the petroleum industry have been losing students in recent years. This shift

[41] An estimate of the petroleum rent has been deducted from the value creation figure for Operators.

mirrors the rising interest in engineering and related topics with a focus on renewable energy and other perceived environmentally friendly technologies.

For doctoral studies, both the absolute number of students and the relative proportion of doctoral students focused on engineering and related fields to other doctoral students are declining. As doctoral studies have the longest time horizon, investments in such studies indicate that there are opportunities for either advanced employment or a future academic life within the specific area of study. Therefore, the declining attractiveness of doctoral programs in the relevant areas might constitute an early signal of declining opportunities for advanced R&D-based value addition in the oil and gas industry.

10.1.4 Talent attractiveness

The industry has closed the gap relative to the national education level. However, it does not attract more specialized labor than is available in the overall population. Furthermore, the industry has gone through a professionalization process over the past decade, as six percent of its high school and middle school-educated workers have been replaced with university graduates.

Many engineers work in the oil and gas industry. However, in several sectors, including Topside, Geo & Seismics and Operations Support, their share is declining. The most obvious growth in these sectors is among workers with business, economics and other social science backgrounds. If this trend continues, parts of the strong cluster may move away from exploration and the creation of new, engineering-based products and solutions toward the exploitation of already developed products and solutions. Alternatively, parts of the cluster may focus on more labor-intensive activities, such as MMO. The trend is also apparent in the constant level of engineers in Subsea and Drill & Well, where we would have expected an increase. Finally, the industry has attracted many foreign workers in recent years. However, most were hired to take advantage of cost advantages rather than their specialized knowledge.

10.1.5 R&D and innovation attractiveness

Innovations on the NCS related to either field development or improved recovery are mainly the result of practical challenges that need to be addressed. In many cases, innovations come about as a result of close cooperation between Operators and suppliers in large field developments. This innovation system, which is based on solving practical challenges, has given Norwegian-based companies a head start in petroleum technology.

Oil and gas-related academic research in Norway has been growing, both when measured in terms of the number of academic staff and in terms of the number of scientific publications. Norwegian-based firms also conduct significant R&D. 31 percent of all firms use 4 percent or more of sales on R&D. Furthermore, a number of foreign firms have located their R&D activities in Norway. For example, around 10 percent of Schlumberger's global R&D budget is spent in Norway. Even though these figures are based on a wider definition of the supplier industry, they indicate serious flaws in the OECD's measurement of R&D and innovation in the Norwegian oil and gas industry. Therefore, we find that Norway's persistently high level of productivity and per capita incomes is not really 'puzzling'.

The Norwegian oil and gas industry innovates more than the other Norwegian industries in terms of products, services and organizational practices. Subsea has been very innovative in recent years, while product and service innovations in Topside and Operations Support have

declined or remained constant. Being the first to the market with a new innovation is the primary method of protecting innovations in the industry.

If the future holds less activity on the NCS and fewer large field developments, the NCS might become a technological backwater. This may force the supplier industry to look to foreign oil and gas hubs for knowledge and learning. Furthermore, the Statoil-Hydro merger reduced competition on the Operator side dramatically. Both of these developments are likely to push the supplier industry towards constructing a non-Operator-centric innovation system – a formidable task taking into consideration that the system has been Operator-centric for over 40 years. If activity in field development declines and hence the current demanding customers (Operators) become less demanding of novel solutions, Norwegian firms may lose their first-mover advantage. They will then need to find other mechanisms to replace the demanding customer mechanism (Porter 1990; Porter 1998).

10.1.6 Ownership attractiveness

When oil and gas activities began in Norway, the country already possessed an international maritime industry, and industrial actors within the fields of fabrication and construction. However, Norway lacked oil and gas-specific competencies. The Norwegian government therefore introduced policies to attract global competence. Starting in the early 1970s, Norwegian policies concerning the structure of the national oil and gas industry followed one direction for Operators and another for Suppliers. For Operators, it became imperative to establish a state-owned company alongside the global companies. For Suppliers, the primary concern was to increase the value creation in Norway, regardless of ownership. As a result of this dual policy, the current share of foreign ownership in the total Norwegian oil and gas industry (37%) is much lower than the share of foreign ownership among suppliers (just above 50%). This focus on foreign-owned companies distinguishes the elements of 'infant industry protection' in the build-up of the Norwegian oil and gas industry from other countries' experiences.

In addition to the effect of Norwegian governmental policies, one reason for the large share of foreign ownership, especially in the suppler industry, seems to be that Norwegian-owned start-ups ready to introduce a product to a larger market tend to look for global industrial partners with financial strength. In this regard, foreign takeovers of Norwegian-owned companies do not harm the development of the national clusters if R&D and headquarter functions remain in Norway. This mostly occurs when the R&D is grounded in Norway, as in the case of subsea technology. The last 10-15 years have seen the emergence of strong Norwegian equity companies involved in private equity (Hitec Vision), venture capital (Energy Ventures) and in industrial ownership (Ferd).

10.1.7 Environmental attractiveness

The oil and gas industry is currently perceived as not very environmentally friendly. The Norwegian oil and gas industry can improve its environmental status by introducing more environmentally friendly solutions and standards. In this regard, many environmentally friendly technologies create win-win situations, as less damage is caused to the environment and more value is extracted. For example, when CO_2 is pumped into an oil well, its pressure increases and the rate of oil extraction increases. There are ongoing initiatives, such as the utilization of microorganisms, to produce win-win solutions.

Furthermore, the Norwegian oil and gas industry's environmental standards make it an attractive oil and gas hub in which to do business. This aspect needs to be emphasized further.

However, the development of higher environmental standards is called for, particularly given the plans to extract oil and gas in the northern areas. Norway must be at the forefront of the global industry in terms of developing environmentally friendly solutions.

10.1.8 Cluster dynamics

The innovation system in the Norwegian oil industry is based on a high degree of collaboration between suppliers of technology solutions and their customers, the Operators. Well-developed collaborations between sophisticated customers and advanced suppliers are important for innovation and internationalization. The advancement of the suppliers of the industry's supplier firms should be a priority. Furthermore, if national oil and gas operations decline, the importance of test facilities and, hence, of R&D institutions is likely to increase.

The system of intra-industry labor mobility is both Operator-centric and technology heavy cohesive grouping. It is Operator-centric because Operators are the preferred employment destination in this system. They receive disproportionate amounts of labor from other sectors within the oil industry but provide very little employment to these sectors in return. It is technology heavy cohesive grouping because there are disproportionately large and reciprocal labor movements, especially among Geo & Seismics, Drill & Well and Subsea.

Clusters thrive in the presence of related clusters. The oil industry has woven a tight network of relations, supported by the transfer of labor to and from the maritime industry, the metal processing industry and advanced knowledge mediators, such as DNV and technology consulting firms. A vibrant community of businesses contributes directly to the success of the oil and gas industry.

Firms in the oil industry invest in competence development as much as firms in the health industry, although the latter is considered to be a much more knowledge-intensive industry. If we combine the intra-industry labor mobility findings with the fact that the main focus of recruitment is on people with industry experience, a reduction in the activity level of the supply industry will also affect Operators, as competent labor gains its experience in the supply industry before moving to Operators.

10.2 Recommendations for business strategy

1) The future of the Norwegian oil and gas industry

> *Prepare for decades of maintenance, modification and decommissioning.* The market for maintenance and modification will grow as the Norwegian oil and gas industry matures. As installations are eventually abandoned, the market for decommissioning will grow as well.
>
> *Prepare for decades of 'difficult' oil and gas production in an increasingly cost-sensitive environment.* Oil and gas production in Norway will continue for many decades but the remaining oil and gas will be increasingly difficult to access. This creates enormous potential for cost-effective technological developments that are designed to improved recovery rates.
>
> *Prepare for increasing low-cost foreign competition, which will initially be evident in the labor-intensive sectors of construction and manufacturing.* The imitation of locally developed solutions and the cost advantages enjoyed by other countries in installation

construction and equipment manufacturing will force a number of the activities currently conducted in Norway out of the market.

2) Cluster attractiveness

Future localization of activities. Regions differ considerably in terms of their sector specialization and their availability of human capital. Future location decisions should take the existence or lack of regional clusters into consideration. This may have direct implications for investments in northern Norway.

Internationalization through the establishment of foreign subsidiaries by Norwegian headquarters. Even though projected investments on the NCS are at an all-time high, the declining reserves make internationalization an imperative. However, to successfully internationalize, Norwegian-based companies must establish local subsidiaries run by local employees.

Improving financial services to smaller and mid-sized oil and gas suppliers. Opportunities exist for financial institutions to increase the breadth of specialized financial services offered to companies that outgrow regional and national financial institutions.

3) Educational attractiveness

Promotion of the industry. To help increase the critical supply of engineers to the industry, firms and their interest organizations should engage in industry-wide activities to promote the industry to prospective employees.

4) Talent attractiveness

Attracting Norwegian nationals. To help increase the critical supply of engineers to the industry, companies should work to promote the oil and gas industry as an interesting, long-term career for promising candidates. The uncertainty surrounding the future of the industry does little to assist in attracting top talent.

Attracting expatriates. To help increase the critical supply of engineers to the industry, companies should work to attract foreign nationals or establish subsidiaries abroad to make use of foreign competences.

5) R&D and innovation attractiveness

Striking the right balance between technologies for exploration and technologies for exploitation. The emergence of new technologies for exploration activities has been the defining characteristic of oil and gas activity on the NCS. The reduced number of new discoveries on the NCS will shift the balance between exploration and exploitation towards a stronger focus on exploitation. The technological challenges involved in the adaptation process should not be underestimated.

Investing in R&D and collaborations with R&D institutions. The dual effect of the increasing focus on costs and the focus on improved recovery implies that firms

should invest heavily in their own R&D capacities and in collaborations with R&D institutions.

Channeling learning from foreign oil and gas activity to Norwegian-based R&D communities. The impetus for innovations developed by the Norwegian oil and gas industry has been the emergence of practical challenges in large field developments on the NCS. As the NCS is likely to have fewer large field developments in the future than foreign oil and gas provinces (Brazil, West Africa, etc.), the impetus for technological development will increasingly be found abroad. Norwegian-based R&D communities must, therefore, base their activities on finding and solving practical challenges found abroad.

6) Ownership attractiveness

Investment opportunities for Norwegian equity holders. The relatively low level of Norwegian ownership on the supplier side of the oil and gas industry, combined with its positive outlook for the years to come, creates a good investment environment for Norwegian equity holders.

Foreign ownership motivated by local knowledge. Foreign ownership constitutes an innovation pressure mechanism. However, the motives for foreign ownership are important. Local firms will be more attractive to the extent to which foreign owners are buying local, sticky knowledge rather than physical assets or access to fluid, codified knowledge.

7) Environmental attractiveness

Proactive vs. passive environmental involvement. The industry has to explore new environmental solutions (such as ways of eliminating oil spill effects if an oil spill occurs). It must take a proactive role to be one step ahead of legislators and interest organizations. Events over the last 12 months, for example, indicate that the industry has yet to appropriately respond to some of the major risks associated with oil and gas extraction.

8) Cluster dynamics

Establishment of a new petroleum innovation system. The Norwegian oil and gas industry is operator and NCS-centric but this will change if the activity level on the NCS declines. New constellations of collaborative relations need to be investigated, and firms need to explore new relations and generate incentives to innovate that are not necessarily dependent on the 'Big Brother' (NCS Operators). One possible development would be a collaboration between technologically advanced suppliers and system integrators for the development of globally unique solutions.

Leverage in new markets: To diversify, suppliers should explore commercially viable opportunities based on their core competencies for markets outside the oil and gas industry.[42] The market for supplies used in renewable energy production – as explored by

[42] The geographical diversification strategy is being explored by many firms and many more should follow suit. The risks involved in this strategy should be noted (its reliance on the continuous

the NODE cluster and construction firms like Aibel and the Bergen Group – has gained the most media attention. However, the future direction of the supplier industry does not have to be related to energy – what is important is the application of core competencies. Given the high cost level in Norway, these applications will have to be highly engineering intensive.

- There are a number of potential markets for the supplier industry, including:
  - Industrial machinery – The drilling equipment produced by the NODE cluster and the fabrication cluster south of Stavanger is essentially industrial machinery.
  - Systems for process industries – The multiphase meters of subsea fame are managing processes that could be used for process industries.
  - Space exploration – The technologies used for subsea activities (remotely operated vehicles, etc.) are similar to technologies used in space.
  - Mining – Competencies related to Geo & Seismics and to Drill & Well are relevant for mining.
  - Construction – Knowledge and solutions related to erosion, resistance and tolerance may be applied in the construction industry.
  - Minerals and biological materials – Knowledge of continental shelf minerals and biological materials could be used for other purposes.

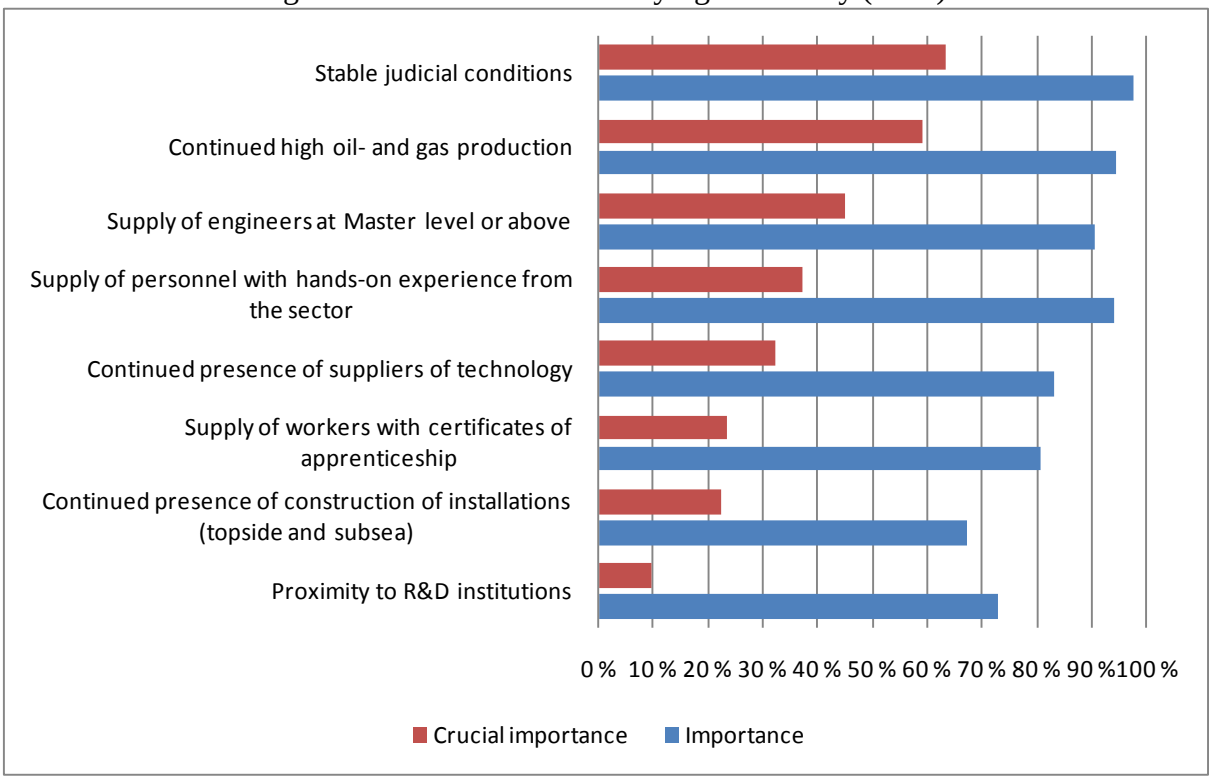
10.3 Recommendations for public policy

As has been shown in section 2, the overarching goal of Norwegian policies for the oil and gas industry has been value creation in Norway. This goal has been achieved though the adoption of a dual policy of attracting global oil and gas companies, and stimulating the build-up of competence and capital. Today, the question how public policy can contribute to further value creation in Norway when the size of discoveries on the Norwegian shelf is declining and other offshore provinces are growing in importance.

Figure 10-1 shows the factors that executives from Norwegian-based oil and gas companies find important in terms of continuing the development of their businesses from Norway. Respondents rated seven statements on a scale from 1 (no importance) to 4 (crucially important). The blue bar indicates the share of firms that rated a condition as being of importance (i.e., ratings of 3 or 4), while the red bar indicates the share that rated a condition as being of crucial importance (i.e., rating of 4).

dependency of energy markets on oil and gas; and the difficulties of providing oil and gas products and services in an industry that is heavily regulated, mostly to the benefit of local suppliers and operators).

Figure 10-1: Conditions for staying in Norway (2010)



Sources: IRIS/BI Survey

1) Continued oil and gas activity in Norway

As the chart shows, the most important condition for further development of the Norwegian oil and gas cluster is that the home market stays intact. Stable judicial conditions, and continued high oil and gas production are rated as important by 98 and 94 percent of the respondents, respectively. Around 60 percent of respondents find these two conditions to be of crucial importance. This result should be seen in conjunction with the finding that activity on the Norwegian shelf provides Norwegian-based suppliers with a natural laboratory for developing technologies that can then be exported to other oil and gas provinces.

> "There is a fundamental 'disconnect' in the current Norwegian debate, namely that we will be able to live off of knowledge alone after the end of the oil 'adventure'. But knowledge does not arise out of nothing. It tends to be based on experience from very specific activities – in many cases, the handling of natural resources." Senior executive, major global operator

2) Supply of engineers

The second most important condition for the further development of the Norwegian oil and gas cluster is the supply of personnel. 45 percent of respondents find the supply of engineers with a degree on at least the Master's level to be of crucial importance and 37 percent find the supply of experienced personnel to be of crucial importance. The supply of workers with a certificate of apprenticeship is also seen as important but only 23 percent feel this is of crucial importance. These results are in line with this report's finding on the oil and gas industry's increasing reliance on engineers and on the increasing problems with the supply of engineers.

> "In the early days of the oil industry, you could land a job without any formal education, provided that you were handy and tolerably smart. This has changed. Of our employees, around 2/3 have a certificate of apprenticeship and 1/3 have a higher education. Due to the increasing use of ICT-based remote operations [Integrated Operations], the relationship between competence categories is likely to be reversed, and we will probably wind up hiring two engineers for every worker with a certificate of apprenticeship." Head of HR, Halliburton Norway

> "We have problems finding enough Norwegian engineers and we therefore have to use 'expats' that are about three times more expensive. It seems that Norway is not educating enough engineers." CEO, large operator

3) Continued presence of suppliers of technology
The third most important condition for further development of the Norwegian oil and gas industry is that suppliers of technology stay in Norway. 83 percent of respondents find this to be of importance and 32 percent see it as crucially important. This result coincides with this report's finding that the Norwegian oil and gas industry is a complete cluster in which innovation occurs in close collaborations between customers (Operators) and suppliers. Should the reduced relative importance of the Norwegian shelf imply that large foreign operators significantly diminish their presence in Norway, important suppliers may start to leave the country and the cluster may begin to disintegrate.

> "We have many sources of R&D, both in-country and abroad. The main reason we are located where we are is that the current management is from the region and prefer to live here." CEO, oil and gas supplier

Knowledge-based industrial public policy: Recommendations

Develop new knowledge through increased activity on the NCS: The NCS serves as a natural laboratory where hands-on results in one field can be applied in another and then marketed globally. Challenging projects are the driving force behind many of the most important innovations in the sector. A decline in local challenges will, therefore, not only affect the attractiveness of the industry to local labor and investors but also deprive the export-oriented parts of the industry of a natural laboratory for technology development. When considering the possibility of opening new areas to oil and gas activity, the government should bear in mind that such an opening will provide the industry with a laboratory for testing potential new technological developments.

Invest in knowledge to fit future environmental standards: The development of higher environment standards is called for, particularly in light of the plans to extract oil and gas in the northern areas. The government should set unprecedented environmental standards that not only secure the environment in northern Norway but also allow the Norwegian oil and gas cluster to remain at the forefront of environmentally friendly solutions.

However, the government must also create the conditions under which technologies that can address future environmental safety standards can materialize (e.g., through incentives to conduct firm and institution-based R&D).

Formal knowledge supply: To ensure a reliable supply of engineers at the necessary level, the government should promote science-based education at an early age. Although the government has a policy of letting the higher education market decide curriculum composition, it sets the curriculum for students up to university level. This curriculum is the basis upon which demand for higher education programs is formed. For the last decade, data has indicated that the trend is clearly moving towards studies of the social sciences and away from studies of the natural sciences, including engineering.

Knowledge imports: To make up for the lack of Norwegian engineers, the government should consider the Australian and Singaporean models for attracting highly educated immigrants. Over the last decade, Norway has primarily attracted immigrants with low educational levels. An incentive-based immigration program that aims to attract knowledge workers is therefore appropriate.

Taxation and knowledge: The current petroleum tax system – the special petroleum tax of 50% for license accounts (including all R&D costs with relevance for the NCS) and the government's pledge to refund the total tax value (78%) of investments for operators not in a tax-paying position – provides incentives for investments, exploration and R&D, *and* levels the playing field between existing and new operators. However, should the size of fields on the NCS and, thus, their relative economic profitability be reduced, the government should consider a revision of the tax system to reduce disincentives for the application of knowledge.

Investments in 'knowledge infrastructure' that provide incentives for suppliers to maintain headquarter and R&D functions in Norway. To assist Norwegian suppliers in adapting to an environment with reduced activity on the NCS and with more distant relations with Norwegian-based operators, the government should invest in 'knowledge infrastructure' by:

- Increasing funding for petroleum-related research programs, such as PETROMAKS and DEMO2000,
- Increasing funding for the 'industrial PhD program',
- Increasing investments in the NCE and Arena programs, and
- Providing funding for advanced test facilities in collaboration with R&D institutions and NCEs.

> "In 2005, China filed more patents than the EU. To assume that Norway in the future will manage to compete with developing economies based on 'knowledge alone' is, at best, 'dream think' and, at worst, a very questionable view of human potential. The activities in which Norway will best be able to compete are knowledge-intensive activities based on the handling of offshore petroleum or other natural resources unique to Norway." CEO, major oil and gas supplier

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12 Appendix: Methodological issues

12.1 Data material

Our research provides a systematic inquiry which aims to provide information useful for decision makers operating in both businesses and public authorities. The management study field is characterized by no clear predominance of qualitative or quantitative studies. The problems addressed by management research are complex and the sheer adherence to either a qualitative or quantitative approach may be an inadequate manner to tackle this complexity (Creswell, 2009). Furthermore, both qualitative and quantitative approaches are suboptimal in the sense that they contain inherent disadvantages when applied in isolation. The mix of methods is advantageous in terms of allowing for triangulation of insights originating from quantitative data with insights originating from qualitative data or vice versa. Such a complementary design is most suitable for the problem at hand. The current situation of multiple Norwegian industries and their current and future capacity to create value is complex, with multiple concurrent forces affecting its current status and expected development.

We employed the concurrent triangulation approach (Creswell, 2009; Creswell et al., 2003). The concurrent triangulation approach implies that the two data sources are compared to determine if there is convergence, differences, or some other combination (Creswell, 2009). The method is often used to offset the shortcoming of the other method. Inferences from each data source are often presented side-by-side to highlight the insights from the different sources (Creswell, 2009).

In this research we utilized a large number of quantitative data sources. We focus here on the employee-employer matched database, accounting database, ownership database, the innovation database and the survey. In addition, we used data sources containing data regarding students and education alternatives in Norway, academic staff, academic publications, and patenting activity in Norway.

Employee-employer matched database contains employment information for all employees working in the private sector in Norway. The database utilized here does not include governmental agencies like the governmental departments, the Army, and local authorities. Statistics Norway compiles the information from its own registers and from the Norwegian Tax Administration and the National Population Register. The data contains anonymized individual data including the individuals' place of employment, age, gender, nationality, place of residence, place of work and the highest education level achieved. The database includes employee based information from 2000 to 2008.

R&D and innovation database is our primary source of R&D and innovation data. The European Innovation Scoreboard (EIS) provides an annual benchmarking of national innovation performance levels across the European Union and internationally. Statistics Norway is responsible for the generation of the innovation statistics in Norway which constitute an important part of the European Innovation Scoreboard. In this research we utilize data from both the innovation survey and from the R&D survey. The data is based on a sample of firms as oppose to the population of firms. For example, for the 2008 data collection, 6029 firms replied. The aggregated turnover of the responding firms was NOK 2.7 billion or about 50% of the total turnover by all Norwegian firms in 2008. The data includes, to name a few, information on investment in R&D, the utilization of R&D personnel,

financing of R&D, product, service and organizational innovations, and the method of protecting innovations.

Accounting database is widely used in research and by businesses. Firms are obliged by law to provide audited balance sheet and profit and loss statements to the Brønnøysund Register Centre. In addition to the balance sheets and profit and loss statements, the dataset contains other firm information including establishment year, geographical location, contact information and industrial affiliation. The data is available from 1992 to 2009.

The *Ownership database* contains information about the ownership of Norwegian firms. Norwegian businesses also have to provide detailed information about their owners including the identity of such owners and the percentage ownership stake that they hold. The data is available for the years 2000 to 2008. The coverage of information increases from year to year.

The Knowledge-based Oil and Gas Survey was conducted using the tailored survey design method (Dillman, 2000; Dillman, Smyth, and Christian, 2009). This method builds on social exchange theory (Blau, 1964) and applies it to survey design and execution. The methods aim to increase the perceived rewards for respondents, decreasing costs of responding and establishing trust so that people believe the rewards will outweigh the costs of responding (Dillman, 2000). We conducted activities that aimed at addressing these three aspects in designing and executing the survey. We received 299 replies which denote a response rate of 21.3%.

The primary aim of the survey was to gather data relevant for the assessment of the degree of interaction or dynamics between actors in the economy that we could not access through secondary sources. The foci were on firm interaction with other entities including public authorities, competitors, alliance partners, customers and suppliers, on the extensiveness and size of the firm customer and supplier bases, and on firm workforce and its workforce investments.

We complemented those databases and survey with semi-structured interviews, participation of industry seminars and conferences and dedicated case studies. We conducted formal interviews with oil and gas operators and suppliers, interest organizations, and financial institutions. We further conducted numerous informal conversations with these and other actors over the entire research period. The interviews provided us with unique access to decision makers in private firms, interest organizations and public authorities and allowed us to explicate the mechanisms the drive our quantitative findings. Case studies were used to illustrate theoretical dimensions. Cases are a preferred method for examining contemporary issues that do not require manipulation of action (Yin, 1989). They rely both on direct observation of a phenomenon and interviews of the involved actors. This allows for triangulation of evidence, mostly qualitative and quantitative for the generation of understanding and knowledge about the phenomenon.

12.2 Establishing the size of the Norwegian oil and gas industry

From the very start of the Norwegian oil and gas story, there have been discussions on how to properly gauge the size of the oil and gas industry i.e. how to define what should be included in ‘the supplier industry’. In the early 1970s, the Norwegian authorities realized that confining the industry to activities registered with either NACE code 06 (operators) or 09.1 (support activities), would overlook a large number of important suppliers that would register using other NACE codes e.g. yards constructing platforms and owners of supply vessels. From 1973

to 2003 the Norwegian Agency for Employment (Aetat) provided annual surveys of petroleum-related employment based on a population of petroleum-related firms developed through the insights of the local employment offices. In 2003, the final year these surveys were published, Aetat collected data from 800 firms with a total employment of 76,608 (Vatne 2007). In the same year, the employment in activities registered with NACE codes 06 and 09.1[43] was only 28,775. In other words, the officially registered employment of the oil and gas industry was about one third of its true size.

In a report commissioned by the Department of Oil and Energy, Vatne (2007) builds on Aetat's work and finds that the supplier industry in isolation (i.e. excluding Operators) consists of 972 firms with a total employment of 96,962, of which 84,622 is related to petroleum. Vatne's definition of the oil and gas industry is stricter than the one used by Aetat as he excludes what he sees as generic activities like catering, public administration of the industry and construction of onshore facilities. A report from 2009 (Konkraft 2009), estimates total employment of the oil and gas industry at 150,000 by combining the employment in NACE codes 06 and 9.1 (40,000), employment in refining, plastics and chemical industry (20,000) and the figure from Vatne (90,000). However, the figure of 150,000 is subject to double-counting as the employment of 20,000 in NACE code 9.1 (support activities) is also included in Vatne's figures. Econ (2010) and Ernst & Young (2009) estimate the employment in the supplier industry to be 91,467 (2008) and 80,000 (2009) respectively consistent with Vatne (2007).

Early in 2010, a program on Norwegian Public Broadcasting (NRK) claimed that the oil and gas industry employed 250,000 people in Norway[44]. In a recent report on the oil and gas industry's impact on the Norwegian economy (Eika *et al.* 2010b; Eika *et al.* 2010a) Statistics Norway estimated that in 2006 a total of 186,000 employees were directly or indirectly related to the oil and gas industry.[45] [46] However, the figure of 186,000 includes employment in generic sectors often excluded from definitions of the oil and gas industry (see for instance Vatne, 2007, Ernst & Young, 2009 and ECON, 2010): Retail and wholesale (24,000), Land transport (12,000), Public administration (7,000) and Primary industries including fisheries (3,000). By excluding employment in these generic sectors, oil and gas related employment will be no higher than 140,000. If, in addition, parts of the related employment in Other services (54,900) are also excluded, the employment will drop somewhat further.

For the purpose of this project, a brand new population of companies related to upstream oil and gas has been established. This work proceeded in three stages. The first stage consisted of joining firms and firm categorization from the following three sources:

- SSB data on firms in petroleum related NACE codes including: 06 (Extraction of oil and gas), 09.1 (support services), 30.112 (Construction of oil platforms), 30.116 (Modification of oil rigs and modules), 50.204 (Maritime services for offshore operations), 52.223 (Supply bases) and 71.122 (Geological surveys). This

[43] The NACE codes were revised in 2007, the NACE codes that in 2003 corresponded to 06 and 09.1, were 11.1 and 11.2 respectively.
[44] "Det nye landet – Arbeiderne" ("The new country – The workers"). Norwegian Public Broadcasting (NRK) 13.01.2010 (ECON, 2010).
[45] The report estimates that by 2009 the total employment will have reached 206 000 or about 8 percent of total employment.
[46] A related publication by the SSB (Johannessen *et al.* 2010) restricts the oil and gas sector to NACE codes 06 and 09.1 + "Construction of oil rigs and modules", "Modification of oil rigs and modules" and "Supply bases", and finds a total employment of only 43 017 persons in 2009.

methodology roughly coincides with the approach used by SSB (Johannessen *et al.* 2010).

- A database on the maritime industry including offshore operations prepared by Menon Business Economics
- A database on oilfield suppliers developed by Ernst & Young Rogaland (Ernst & Young 2009). It was generously made available for use in this project.

To focus on the industry as such, governmental agencies (e.g., the Norwegian Petroleum Directorate), branch organizations (e.g., the OLF) and education/research institutions (e.g., SINTEF, CMR, and IRIS) were left out of the population.

The next stage consisted of checking the accuracy of the resulting database:

- To ensure that all licensees/operators were included, a list of license holders was obtained from the Norwegian Petroleum Directorate
- General knowledge of the industry was used to scan for missing firms
- General knowledge of the Norwegian economy and information on firm websites were used to find or delete firms
- The employment pages of the main daily newspaper in the Stavanger region were scanned.

The third stage consisted of placing the firms in one of six sectors using a combination of:

- Classifications used by Menon Business Economics, Ernst & Young or the NPD (for licensees/operators only)
- General knowledge of the industry
- Information on firm websites (The web pages of all firms in the population were found and analyzed. For those firms without a website, we called the firm directly.)

1) *Licensees/Operators:* Owners of production licenses and operators (e.g. Statoil, Shell, Skagen44)
2) *Geology, Seismics and Reservoir:* Geological analysis, acquisition and processing of seismic data, and reservoir modeling (e.g. Western Geco, PGS)
3) *Drill & Well:* Drilling and well intervention, rigs and FPSOs (e.g. Halliburton, Seadrill)
4) *Field Development Topside:* Engineering, construction and maintenance of topside installations like vessels, FPSOs, rigs and platforms (e.g. Aker Solutions, Bergen Group)
5) *Field Development Subsea:* Engineering, construction, installation and maintenance of subsea installations (e.g. FMC, Aker Egersund, Subsea 7)
6) *Operations Support:* Provision of personnel, equipment and services for the running of offshore production (e.g. renting of personnel, safety equipment, supply vessels, helicopter transport)

To allow for further analysis, each firm in each sector was then classified according to the *activity* in which the firm is engaged, based on NACE codes as follows:

- Engineering-based services: firms within NACE codes 06 (operators), 09 (support activities), and 58-74 and 78-82 (provision of services),
- Manufacturing: NACE codes 22-28 (manufacturing),
- Equipment supply: NACE codes 46 (wholesale) and 77 (rental of equipment),

- Construction and maintenance: NACE codes 30-33 (construction and repair),
- Maritime operations, rigs and FPSOs: NACE 50 (sea transport) and firms manually registered as maritime operations, rigs and FPSOs, and
- Support facilities: NACE codes 38 (renovation), 49 (land transport), 52 (services connected to transport) and 56 (catering).

It should here be mentioned that as the basic unit of analysis is firms (i.e., corporate entities with unique organization number), each firm may only be assigned to one sector (Operator, Topside, Subsea etc.). One may therefore not distinguish between involvements in different sectors or distinguish between oil and gas vs. non-oil and -gas activities. The lack of correction for non-oil and -gas related activities will, in isolation, lead to an overestimation, but this will be counterweighed by the lack of inclusion of firms where oil and gas related activities represent only a small share of total activity. Furthermore, as a matter of simplification, the classification into sectors and activities has been assumed to be constant over time. This simplification naturally implies some inaccuracies if firms have changed sector and activity over the years.

Figure 12-1: Employment in the oil and gas industry (2007-2009)

Sources: Statistics Norway - Employment Register and IRIS/BI

For 2009, the established company population yields a total employment of 136,000, out of which 22,000 can be allocated to Operators and 114,000 to suppliers (Figure 12-1). The employment among suppliers (114.000) is somewhat higher than the figures from Vatne (2007), Ernst & Young (2009) and Econ (2010), but in line with Eika et al. (Eika *et al.* 2010b; Eika *et al.* 2010a) when adjusted for employment in generic activities.