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The Regional Dynamics of Innovation:

A comparative case study of oil and gas industry development in Stavanger and Aberdeen*

Sachi Hatakenaka[1], Petter Westnes[2], Martin Gjelsvik[3], Richard K. Lester[4]

[1]Industrial Performance Center, MIT, sachihata@aol.com
[2]International Research Institute of Stavanger, petter.westnes@irisresearch.no
[3]International Research Institute of Stavanger, martin.gjelsvik@irisresearch.no
[4]Industrial Performance Center, MIT, rklester@mit.edu

Abstract

This paper addresses a central question confronting politicians, business leaders, and economic planners throughout the world: How can local economic communities survive and prosper in the rapidly changing global economy? The paper reports on a comparative case study of two key regions in the North Sea oil and gas province: the Stavanger region on the southwest coast of Norway and the Aberdeen region in northeast Scotland. These two regions proved an ideal setting for a matched pair comparison, as the circumstances under which they developed into oil capitals are strikingly similar. Yet the development of local technological and industrial capabilities followed different paths in the two locations. On the other hand, these differences do not appear to have led to significantly different levels of international competitiveness. Although Stavanger and Aberdeen are characterized by very different local innovation systems, the available evidence suggests that outcomes have been similar along significant dimensions of industry performance.

Keywords: Regional innovation systems, oil and gas, comparative case study

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Introduction

This paper addresses a central question confronting politicians, business leaders, and economic planners throughout the world: How can local economic communities survive and prosper in the rapidly changing global economy? An increasingly common response to this question in recent years has been to focus on ways to strengthen local capabilities for innovation. By 'capabilities for innovation', we mean the ability to conceive, develop, and/or produce new products and services, to deploy new production processes, and to improve on those that already exist.

Local and regional innovation systems have attracted much attention from policy makers as well as academics in recent years, with several strands of literature developing (Breschi & Lissoni, 2001; Cumbers & McKinnon, 2004; Doloreux & Parto, 2005; Iammarino, 2005). The concept of 'national innovation systems' was introduced by scholars of economic and technological change in recognition that a wider set of institutions than the firms directly involved in bringing new products to market are participants in the innovation process (Freeman, 1987; Lundvall, 1992; Nelson, 1993). Porter introduced the notion of 'clusters' as key to industrial competitiveness, further emphasizing the importance of firm interactions with supply chains and with public science (Porter, 1990; 1998). The concept of 'clusters' caught the imagination of policy makers around the globe and helped popularize the idea that 'regions' matter for competitiveness. A closer examination of successful industrial districts such as Silicon Valley, Third Italy and Baden-Wurttemberg led to the idea that local interactions played a special role in such regions (Piore & Sabel, 1984; Saxenian, 1994) and the 'region' was soon proposed as an alternative level of analysis (Acs & Varga, 2002; Braczyk, Cooke, & Heidenrich, 1998; Cooke, 1992). Economists joined the debate with their renewed interest in economic geography and the role of geographic specialization (Krugman, 1991), and 'knowledge spillovers' were proposed as key mechanisms for agglomeration dynamics (Audretsch & Feldman, 1996; Jaffee, 1989; Jaffee, Trachtenberg, & Henderson, 1993).

More recently, there has been a growing understanding that the diverse nature of regions may preclude 'one-size-fit-all' solutions or general 'best practices' for regions, and the need for policy recommendations to be differentiated is increasingly recognized (Cooke & Schienstock, 2000; Tödtling & Trippl, 2005). Various typologies of regional innovation systems have been proposed based on reviews of multiple case studies (Asheim & Isaksen, 2002; Cooke, Heidenreich, & Braczyk, 2004) and the presence of different configurations of competition, collaboration and cooperation has been recognized (Polenske, 2004). But the lack of comparability across regions meant that most of these studies merely juxtaposed different systems, which prevented claims from being made about relative economic performance. In the end, the underlying assumptions about 'successful' regional innovation systems have remained surprisingly uniform in the literature, powerfully shaped by the image of Silicon Valley (Saxenian, 1994). Thus, in spite of the wide recognition that regions are pursuing their own developmental paths, with only limited ability to change course (Heidenreich, 2004), the goal for all regions is to develop the same kind of regional innovation systems based on strong local interactions and the culture of cooperation and competition, as suggested by a handful of successful cases (Cooke & Morgan, 1998). This is perhaps not surprising given the analytical history of the regional innovation system framework, in which 'regions' were proposed as a critical level of analysis precisely because of the importance of local interactions (Cooke, Uranga, & Etxebarria, 1997; Doloreux, 2002).

If regional innovation systems are different systems, each following its own evolutionary path, how do these systems evolve, how do they differ from each other, and what are the implications for economic and innovation performance at the regional level? While these issues have not been much explored in the past, the literature does provide helpful clues as to the circumstances under which different innovation systems are most likely to manifest themselves.

First, there have been discussions about how regions may connect to global industry in different ways (Acs et al., 2002), which in turn may demand different configurations of local capabilities and institutions. Regions may connect to multinational corporations in different ways as the latter make decisions about their locations (Cantwell & Iammarino, 2003). Silicon Valley's dynamism was enhanced by its linkages to other 'hubs' such as in Taiwan (Saxenian & Jinn-Yuh, 2001), and indeed a broader review of New Silicon Valleys showed that connection to sizable markets, in this case in the US, was a significant factor in their emergence as innovative regions (Bresnahan, Gambardella, & Saxenian, 2001). If it is possible for regions to develop different 'innovation systems' because of differently configured links with global industry, it may be worth exploring the influence of such links on the development of these systems.

Second, the conditions of success for any region change over time as circumstances both internal and external to the region change. National contexts for innovation change over time (Freeman, 2002). The factors important for initiating agglomeration dynamics may be different from those that keep the process going (Bresnahan et al., 2001). Once agglomeration sets in, a different concern about 'lock-in' may arise and demand different goals and strategies (Isaksen & Remøe, 2001; Tödtling et al., 2005). Regions may thus experience different demands for their capabilities over time. Consequently it may be worth studying the histories of regions as they grow and mature (Iammarino, 2005).

Finally, since the conditions for successful innovation mechanisms/systems vary across sectors and technologies (Mowery & Nelson, 1999; Nelson, 2000), it may be important to control for these effects by exploring inter-regional variations within the same industrial sector.

In this paper we report on a comparative analysis of the development of the oil and gas industry in Stavanger, Norway and Aberdeen, Scotland, two regions which emerged as 'oil capitals' in the North Sea in the past 40 years (Hatakenaka, Westnes, Gjelsvik, & Lester, 2006). This study is part of a larger research project based at the MIT Industrial Performance Center on the dynamics of innovation system development at the local level, the Local Innovation Systems Project (Lester, 2005). The oil and gas industry is among the most technology intensive and highly globalized of industries. A comparison of Stavanger and Aberdeen affords a valuable analytical opportunity as the circumstances under which the two regions developed into oil capitals are strikingly similar. The two regions developed over the same period, interacted initially with the same group of global oil companies, and faced similar market conditions and geological and technological challenges. Both regions had to struggle with the issue of how to build local capabilities in the context of an already well-established global industry, and both were able to develop industrial complexes of similar size. Oil production in the Aberdeen region has peaked, and in Stavanger will shortly peak, and both regions are today confronting the challenge of how to sustain local innovative capabilities as depletion of the natural resource continues.

But the development of local technological and industrial capabilities in the two regions has followed very different paths. In Norway, the national, regional and local authorities made concerted efforts to develop local capabilities in the oil and gas industry, and to concentrate industry-related institutions in Stavanger. In contrast, the industry in Aberdeen grew despite a lack of consistent support from the national and local authorities.

These differences in the institutional and policy environment, though considerable, do not appear to have led to significant differences in the international competitiveness of the two local industries, at least so far. Stavanger and Aberdeen are characterized by very different local innovation systems, but both appear to have enjoyed similar successes in the race to internationalize and export their expertise to other oil provinces.

In short, these two regions provide an ideal matched pair for analyzing the origins and consequences of different approaches to building local systems of innovation.

Method

Our approach was to conduct a comparative case analysis using multiple sources of data. We relied primarily on semi-structured interviews, supplemented by industry statistics, and the secondary literature on these two regions and the oil industry more generally. It is widely recognized that carefully constructed comparative case studies are valuable for the study of complex socio-economic systems (Asheim, 2002; Doloreux, 2002), particularly in unravelling causal links and underlying mechanisms (Markusen, 1999).

The comparative approach is inspired by the method of structured comparison of two similar cases proposed originally by Mill (1843; Skocpol & Somers, 1980). The main benefit of comparison in this case, however, is not so much to enhance the generalizeability of findings, but to inject rigor into the qualitative understanding of each of the cases, particularly by drawing contrasts between them. This is a particularly powerful approach in well-matched cases, where the circumstantial similarities help highlight the differences in terms of paths taken as well as paths not taken.

We conducted a total of 71 interviews as a key method to explore firm and institutional dynamics. Interviewees were identified in a cascading manner starting with key informants in local governments/industry organizations, and were carefully selected to ensure coverage of different types of stakeholders including different types of firms; different levels of government; universities; and public/private research institutions. 31 interviews were conducted in Stavanger with 29 key informants -- 14 representing industry, 7 from research institutions, 4 from universities, and 3 representing industry-related organizations. In Aberdeen, 40 interviews were conducted with 40 key informants -- 17 representing industry, 8 from government, 9 from three universities and 6 from other industry-related organizations.

To complement the qualitative data obtained from the interviews as well as archival sources, we also conducted studies of patenting and publications in the two regions. We searched the US patent database for all oil and gas industry-related patents cumulatively issuing through June 2005 which met the criterion that at least one of the inventors was located either in the Aberdeen region or in the Stavanger region. We further identified all oil and gas industry-related patents issuing prior to June 2005 for which at least one of the assignees was located in one or other of the two regions.[1] We also searched two major petroleum-focused publication databases -- the e-library of the Society of Petroleum Engineers (SPE) and Petroleum Abstracts -- for publications by authors employed by research and education institutions in the two regions.

Half of our team came from RF-Rogaland Research[2], a research institute in Stavanger that is closely associated with the oil and gas industry. These team members' industry knowledge and proximity to key players in the region was particularly helpful for this research. At the same time, we made conscious efforts to ensure neutrality of our analysis (Markusen, 1999). Non-Stavanger-based team members played a role as 'outsiders' to avoid any 'insider bias,' and a total of 13 (6 in Stavanger and 7 in Aberdeen) interviews were conducted jointly to ensure comparability of interviews. In addition, the analytical results were tested against three key informants from each region to avoid any biases in interpretation (Cumbers et al., 2004; Markusen, 1999).

Overview of the two cases: Stavanger and Aberdeen

Stavanger and Aberdeen developed to become significant oil industry centers, with a similar set of industrial players and similar levels of industry employment (about 37,000 in Rogaland County, of which Stavanger is the largest municipality, and about 39,000 in Aberdeenshire.) In each region oil and gas is by far the largest industry, and the local industry in each region also accounts for an important share of national employment in the oil sector. This is especially true of the Stavanger region, where nearly 50% of Norway's total employment in the oil and gas industry is located, but in the U.K. too, more than 20% of total oil and gas sector employment is found in the Aberdeen region.

The overall levels of oil and gas production were similar in the two regions until recently, although UK production peaked in 1999 for oil and in 2002 for gas, whereas Norwegian production is expected to peak in 2006 for oil and in 2010 for gas.

Exports of oil-related services are an increasingly important performance metric for the two regions, as local oilfields reach maturity. Here, Scotland leads Norway, with 6 billion USD in exports in 2003 compared with 4.9 billion USD from Norway, but this margin is small. Given the fact that the majority of oil-related firms in Scotland and Norway are localised in Aberdeen and Stavanger, it is reasonable to assume that these national export numbers also reflect exports from the two regions.

Neither locality has managed to diversify significantly out of the oil and gas industry to date, though there are on-going efforts, for instance, in renewable energy, supported by respective authorities as well as industry and universities.

Different development pathways

At the outset of the North Sea oil era, both Norway and the UK confronted the problem that they had virtually no local capabilities in the oil and gas industry. Even though the UK was at an advantage, given the broad experience of BP and Shell, the extraction and production of oil required a range of supply industry functions, none of

[1] We defined the greater Aberdeen and greater Stavanger areas by reasonable commuting time. In each case, the area extends roughly 30 miles from the center of the city.

[2] Rogaland Research changed its name to International Research Institute of Stavanger (IRIS) on January 1 2006.

which existed in either country. The first step for both countries, and both localities, had to be to invite foreign companies – most notably the Americans.

The paths subsequently taken by the two countries were significantly different, however. Government policies differed in three important ways: in managing the speed of depletion (by deciding what to license); in the emphasis on domestic capacity building; and in localization decisions.

From the earliest days, the Norwegians saw oil as a national asset to be managed carefully. In contrast, the British government moved quickly to adopt a fast depletion policy, prompting a larger number of foreign companies to move in (Cameron, 1986; Cook, Lesley, & Surrey, 1983). This difference in approach was at least partly dictated by differences in the two countries' macroeconomic circumstances (Noreng, 1980). The British government was preoccupied with a crippling balance of payments crisis, and therefore needed a rapid scale-up of oil production. Norway had close to full employment and generally healthy macroeconomic conditions. Indeed, there were real concerns that if the development of the oil industry was left to market forces, the relatively small Norwegian economy might be overwhelmed; it was sensible for them to move slowly if only to avoid inflation. Environmental concerns and co-habitation with fisheries were other issues.

Domestic capability building was a clear policy priority for Norway from early on. This was reflected in the establishment of a national oil company, Statoil, and in specifying licensing conditions, which often required technology transfer from foreign companies to domestic organizations. The government was systematically evaluating and rewarding foreign oil companies who were contributing to domestic capacity building. Concessionary procedures were used as an instrument to force the international companies to engage in technology transfer and local content development.

Efforts to promote local industrial development in the UK started later, changed over time and did not go as far. On the one hand, the UK oil industry long predated the North Sea oil discoveries and featured major international players like BP and Shell. On the other hand, the fast depletion policy also required technical inputs that only the American oil service companies were equipped to provide at that time. The goal of local capability building was a secondary consideration. The national government later pursued a 'Buy British' policy through the Offshore Supplies Office (OSO), and also established a national company, the British National Oil Corporation (BNOC). However, the UK government was also undergoing a radical change in its economic policies; and the oil sector was seen as too transient and too small to warrant close and consistent attention from policymakers. BNOC was dismantled shortly thereafter, and OSO treated foreign-owned companies in the UK as 'domestic.'

While the regional authorities played critical roles in establishing local education and research capabilities relevant to the oil industry in Stavanger, no comparable efforts were made in Aberdeen, which already had a well established university and a polytechnic.

Local authorities in both locations worked hard to prepare the infrastructure necessary to attract foreign companies; but at the level of the central government there were significant differences in location policy. In Norway, the decision was taken to locate both Statoil and the Norwegian Petroleum Directorate (NPD) in Stavanger. In contrast, Glasgow, which had virtually no oil industry, but which was then confronting serious problems of unemployment and economic stagnation, was selected as the location for both BNOC and OSO, even though Aberdeen was already attracting oil related industry.

Different Innovation Systems

The different pathways taken in the development of the two regions have contributed to the emergence of quite different local innovation systems.

For the oil and gas industry in general, collaboration and interaction between three types of companies are critical for innovation: oil exploration and production companies (also known in the industry as 'operators'), who have the rights to explore oilfields and without whose participation new technologies cannot be tested in the oilfields; integrated service providers, large global companies capable of providing most exploration and production-related services to oil companies; and small specialized suppliers/service companies, which are often the pioneers in developing new technologies. While all three types of companies are present in both regions, the mix is subtly different in each case, leading to different patterns of interactions between them. Stavanger is generally characterized by high levels of both industry and industry-government coordination and collaboration, while the prevailing ethos in Aberdeen appears to be market coordination and competition.

In Stavanger, Statoil, which has grown to become an internationally recognized oil company known for its technology orientation, has played major roles in orchestrating collaboration as a demanding user, as a project sponsor and as a provider of information and expertise. Since 1991, Statoil has operated a program to develop and support innovative supply companies, providing opportunities for the development of local firms. However, the regional impact of this initiative is contested. In Aberdeen, although leading operators like BP and Shell were active in earlier years, these activities have been scaled back since the 1990s and today there is no leading corporate patron of local innovation to match Statoil's role in Stavanger.

While there are complaints in Aberdeen about the lack of collaborative opportunities for innovation (Crabtree, Bower, & Keogh, 1997), Stavanger companies continue to report high levels of collaboration. In a survey conducted in 2003, 55% of SMEs in the Norwegian oil and gas industry found that collaborating with national oil companies was of great importance to their own technological development, while 37% reported that collaborations with foreign oil companies were similarly important (Kristiansen et al 2004). In a separate survey conducted in Aberdeen in 2000, only 30% of SMEs in the oil and gas industry were collaborating with operators at all (Cumbers, Mackinnon, & Chapman, 2003).

On the other hand, Aberdeen is characterized by a larger number of companies, with an estimated total of 900-1000, compared with 500-600 in Stavanger (Aberdeen City Council & Aberdeenshire Council, 2001; BI, 2003; Cumbers, 2000; Frontline Management Consultants & Ron Botham Associates, 2000; Jakobsen, Vikesland, & Moen, 2000; Leknes & Steineke, 2001; MacKinnon, Chapman, & Cumbers, 2001; Trends

Business Research, 2001)[3]. Aberdeen hosts a more diverse group of operators, with nearly three times as many independent operators as Stavanger. Most of these companies do not have internal technological capabilities, and so they are often willing partners in trying new ways of doing business, and thus provide different opportunities for innovation to suppliers. These differences are not necessarily permanent – it is possible that they merely reflect differences in the maturity of oilfields, which could narrow/disappear over time. In this regard, the number of independent operators in Stavanger has risen rapidly in the past couple of years.

The second main difference concerns the nature of innovation. Stavanger has developed a reputation for technology-driven innovations, while Aberdeen is known for its operational innovations. Such reputations are consistent with industry benchmarking data. Aberdeen leads Stavanger in terms of cost competitiveness. The Norwegian industry is known for high costs, which in turn are partly associated with generally more severe regulatory requirements (Kon-Kraft, 2004). On the other hand, industry benchmarking also suggests that Norway leads the UK in the use of new technology, and Norway is seen as 'a test-bed for new technology.' (Duncan, 2001). The high cost level and a benevolent tax structure are major drivers for exploiting new technology.

Such a difference in orientation is consistent with the way Stavanger and Aberdeen have attracted the four integrated oil and gas industry service providers. Stavanger has become the North Sea headquarters of Schlumberger, which has a reputation as the most scientifically oriented of the four and which has established a significant research capability in seismic and reservoir monitoring there. Aberdeen has attracted Weatherford, which is known for its operational orientation, and which has concentrated its research and training activities in more operationally relevant fields. Baker Hughes, which also set up its North Sea headquarters in Aberdeen, is focused on operational rather than technology-related activities there. The fourth integrated service company, Halliburton, is equally present in both regions.

Similarly, differences in the characteristics of the most visible small innovative companies are also consistent with this difference in technological orientation. In Stavanger, the most salient of the small innovative companies arose from local technical research capabilities. Roxar ASA is recognised as an industry leader in specialist software and grew directly out of the R&D unit of another local company. Hitec, another Stavanger-based company, is known for its early innovations in computer-controlled remote drilling, and its technology arose directly from joint industry projects undertaken by the regional research institute RF-Rogaland Research.

In contrast, the most visible small firms in Aberdeen were founded by individuals who had previously worked in global oil industry companies, gained significant operational experience internationally, and developed many of their ideas directly from such experience. Andergauge is one such example. The original idea for its innovative drilling equipment was developed by its founder, based on his extensive international

[3] The estimates emerge as means from a wide range of attempts to identify and map the petroleum related industry in Scotland and Norway. The estimates vary depending on how the companies are counted, which criteria are used to define the cluster, and which geographical parts of the two regions are included in the counting. The estimates reflect total number of companies including companies within the cluster's core, such as oil companies, engineering and construction, and supplier companies who depends heavily on business from the oil and gas sector. These include not only drilling and service companies, but also companies within maritime transport, catering, ICT, and commercial service.

operational experience in drilling, gained while he was employed in several US companies. Similarly, the innovative ideas of PES, the pioneer in smart well technology, came from its founder who had developed the concepts based on his extensive international field experience in Schlumberger and Shell.

None of the educational or research institutions in either region have had explicit policies to support 'spin-offs' until recently. When RF adopted more proactive policies in the latter part of the 1990s, it was able to quickly establish a portfolio of 20 companies, and discovered that a number of companies had been formed from the results of its past research. In contrast, there is only one on-going case of a technology-based university spin-off in Aberdeen, with other previous examples of university-related companies mainly in non-technical fields.

As another indicator of inventive activity, we compared patenting behaviours in the two regions. We found that the total number of US patents in oil and gas-related fields with at least one Aberdeen-based inventor is more than twice the number associated with Stavanger-based inventors (see Table 1.) This is an intriguing result, given the reputation of Stavanger as a technologically driven location. Possible explanations include differences between the regions in the degree of connectivity to the US oil and gas industry, as well as more general differences in the propensity to seek patent protection.

Table 1: U.S. oil and gas industry-related patents with a connection to Stavanger and Aberdeen (cumulative through June 2005)

ABERDEEN		STAVANGER	
	No. of Patents		No. of Patents
With at least one Aberdeen assignee	177	With at least one Stavanger assignee	251
With at least one Aberdeen inventor	756	With at least one Stavanger inventor	307
Total Aberdeen-Related Patents	780	Total Stavanger-Related Patents	412
(Patents with both Aberdeen assignee and Aberdeen inventor)	(153)	(Patents with both Stavanger assignee and Stavanger inventor)	(146)

Source: US patent database

Table 2 suggests that one key contributor to the regional difference in patenting patterns is the greater role of US firms in Aberdeen than in Stavanger. 366 patents, or nearly half the total number of patents with Aberdeen-based inventors, were assigned to US companies, whereas only 86 (28%) of the patents with Stavanger-based inventors were assigned to US companies. It may also be significant that the three American integrated service companies with a presence in both locations received a considerably larger number of patents on the basis of Aberdeen-related inventions than from Stavanger.

Table 2: Location of patent assignees for Aberdeen-based and Stavanger-based inventions (through June '05)

ALL PATENTS WITH AT LEAST ONE ABERDEEN-BASED INVENTOR		ALL PATENTS WITH AT LEAST ONE STAVANGER-BASED INVENTOR	
Assignee located in:		**Assignee located in:**	
Aberdeen	153 (20.2%)	Stavanger	146 (47.5%)
Elsewhere in the UK	217.5 (28.8%)	Elsewhere in Norway	60.5 (19.7%)
United States	366.5 (48.5%)	United States	86 (28%)
Other countries	19 (2.5%)	Other countries	14.5 (4.7%)
Total	**756 (100%)**	**Total**	**307 (100%)**

Source: US patent database

Another possibility is that these results reflect underlying differences in the level of inventive activity in the two regions. A third possibility is that there are locational differences in the propensity to patent. The latter explanation was also suggested by comments from our interviewees. Regional differences in the propensity to patent may in turn reflect differences in corporate 'knowledge' strategies (Cohen, Nelson, Welsh, & John, 2000), and they may also reflect broader national differences in patenting behavior. There is some evidence to support this last possibility. In 2001, for example, 3965 US patents were granted to inventors located in the UK and 295 patents were granted to Norwegian inventors (NSF 2004). Adjusting these figures to account for the difference in the overall scale of inventive activity in the two countries, using reported R&D expenditures as a proxy, UK inventors in all fields received an average of 170 U.S. patents per billion dollars of R&D expenditures, while their Norwegian counterparts received 96 patents per billion dollars of R&D expenditures.

Roles of universities and public research institutions

Differences between the two innovation systems, both in terms of how they evolved and how they operate today, are exemplified by the different roles played by local universities and research institutions. The institutions in Stavanger developed relevant technological capabilities based on implicit and explicit coordination and collaboration with government and industry. In Aberdeen, the universities developed ties to industry not as a result of institutional efforts to respond to industrial needs, but rather through the actions of individual academics in a diverse range of disciplines.

Both the university in Stavanger (UiS) and Rogaland Research (RF) were created more or less coincident with the founding of the oil industry in the region. Established in 1969 as a regional college, UiS always saw its role as serving the educational needs of local industry, and developed key capabilities in relevant fields such as petroleum engineering. Working closely with the oil and gas industry to provide key educational programs was a natural part of its mission. RF was created in 1973 by the regional authorities, originally as the research arm of the college. But it soon developed into an independent research institute with capacities to undertake applied research and testing for the oil and gas industry. Taking part in collaborative research with industry was a raison d'etre and an assumption since its foundation, and was aided by government policies which often forced foreign companies to conduct research in Norway.

In contrast, Aberdeen's two universities – the University of Aberdeen and Robert Gordon University (RGU) -- were both well established institutions when the first North Sea oil discoveries were made, and they were not as responsive to the technological needs of the nascent industry. The University of Aberdeen, a 500-year old academic institution, opted out of working with the oil and gas industry, which it saw as a transitory presence in the region. It was only through the efforts of individual academics from a variety of disciplines, including economics, geography, geology and zoology, that relationships were formed with the industry. RGU, a former polytechnic, moved quickly to meet the industry's training needs, and continues to offer petroleum-related graduate educational programs -- though mainly through the use of its location and the importation of external expertise rather than by developing an internal capability.

This is not to say that no UK institution developed technical capabilities to meet the needs of the oil and gas industry. Heriot-Watt (HW) University, located in Edinburgh, about two hours by train from Aberdeen, developed a national and later international reputation for petroleum engineering, but largely through its own initiatives. Once HW had taken the lead in developing industry-relevant technological capabilities in petroleum engineering, competition made it harder for either of the Aberdeen institutions to develop similar fields of specialization. Imperial College also already had an established reputation in petroleum related fields at the time of the first North Sea oil discoveries.

RF and UiS can also be contrasted with what in some respects are their institutional twins in Trondheim, the Norwegian University of Science and Technology (NTNU) and the independent research organization SINTEF, which were both well established by the time the first North Sea oil discoveries were made. In this case, however, RF and UiS moved more quickly to develop applied technological capabilities in petroleum engineering, partly to differentiate themselves from existing institutions such as NTNU and SINTEF.

One key difference between Stavanger and Aberdeen in the role of universities and public research institutions is the extent to which these institutions operated to provide 'public space' (Lester & Piore, 2004) for their industrial partners. This difference is best illustrated by the different ways in which the two regions developed and used similar experimental facilities for drilling. In Stavanger, the drilling facility was developed at RF and played a critical role in helping develop the region's capabilities in drilling, particularly in leveraging joint industry projects with multiple industrial partners. In Aberdeen, a similar drilling facility was developed at a site that was not connected to researchers, and played a role principally as a testing site for individual companies.

The differences in these roles are also suggested by the publication record in two industry-related bibliographies: the papers contained in the E-library of the Society of Petroleum Engineers (SPE); and Petroleum Abstracts (PA), a database administered by the University of Tulsa.

The number of papers published in the Society of Petroleum Engineers (SPE) database is a quantitative measure of application-oriented research relevant to industry (see Table 3.) SPE papers generally do not report on fundamental scientific research, and their coverage tends to center on exploration and production-related petroleum engineering and technology and does not extend to related fields such as geosciences or petroleum economics; nevertheless, the SPE database constitutes one of the most important bodies of codified knowledge for the industry.

Petroleum Abstracts (PA) provides a more comprehensive measure of research contributions covering a broader range of fields relevant to exploration and production, including geosciences, social sciences and economics. In addition, while the SPE database focuses on applied technology, the PA database covers the whole spectrum of publications from basic science to applied technology.

Table 3 shows that the two institutions in Stavanger published 308 papers in SPE between 1990 and 2004, many more than the 70 produced by the two Aberdeen institutions, but roughly the same as Heriot Watt. The pattern of authorship also varies. The majority (around 2/3) of the papers from University of Stavanger and RF were written in collaboration with others. For the University of Aberdeen and Robert Gordon University it is the other way around: around 60% of the papers were written solely by their own faculty.

Table 3: SPE-papers from key research institutions in Norway and the UK, 1990-2004 (% of total papers in parentheses)

	Norway				**UK**			
	Stavanger				**Aberdeen**			
	UiS	**RF**	**SINTEF**	**NTNU**	**UofA**	**RGU**	**Heriot Watt**	**Imperial College**
Written solely by in-house researchers	38 (38%)	74 (36%)	34 (35%)	18 (24%)	24 (55%)	16 (62%)	166 (54%)	92 (59%)
Written in collaboration with others	63 (62%)	133 (64%)	63 (65%)	58 (64%)	20 (45%)	10 (38%)	144 (46%)	65 (41%)
Total	101	207	97	76	44	26	310	157
Regional total	**308**		**173**		**70**		**-**	**-**

Source: estimated from SPE database

More generally, researchers at the Norwegian institutions are more 'collaborative' than their British counterparts. This difference is robust even when collaboration between twin institutions like RF and UiS is netted out (only 5% of the Stavanger papers were written by authors from these two institutions collaborating solely with each other.) In general, the patterns of co-authorship suggest that Norwegian researchers may be more collaborative across organizational boundaries than their UK counterparts.

The two Stavanger institutions can also be compared with the two institutions in Trondheim. Here, we might have expected to find that SINTEF, a public research institute, together with NTNU would have a far greater number of publications than RF and UiS, given their longer history and larger size (SINTEF has about 290 employees in their Petroleum and Energy Division, compared with about 90 in RF Petroleum). While the pattern of collaboration is similar in Trondheim, with about two thirds of the papers co-authored with authors from other institutions, the total number of publications is less than 60% of that of the Stavanger institutions.

Table 4 shows that the contribution from the University of Aberdeen is much greater when the wider range of subjects covered by PA is included. The contribution of Heriot Watt is larger, as before, but on this broader measure the contribution of Imperial College is larger still, and by a substantial margin. Among the Norwegian institutions, SINTEF and NTNU are together more than twice as prolific as RF and UiS.

Table 4: Number of Publications in Petroleum Abstracts (1965-2005)

Institution	Publications in Petroleum Abstracts
UiS	248
RF	574
NTNU	1020
SINTEF	810
Aberdeen	586
RGU	48
Heriot Watt	1073
Imperial College	1473

Source: Petroleum Abstracts

These data confirm our qualitative findings that the Stavanger institutions specifically developed application-oriented research capabilities in petroleum engineering fields, on a scale comparable to Heriot Watt and on a larger scale than that of the University of Aberdeen (or indeed SINTEF/NTNU or Imperial College). However, once a broader array of academic subjects is included, the University of Aberdeen is at least as prolific in producing industry-relevant research, and the contributions from other institutions such as NTNU/SINTEF, Heriot Watt and Imperial College are correspondingly larger. A striking difference was found in the level of collaboration across institutional boundaries; Norwegian institutions were consistently more collaborative with industry than their UK counterparts – suggesting that they may have been more effective in providing ‘public space’ to their industrial partners.

Discussions and conclusions

Stavanger and Aberdeen have clearly taken different paths in exploring and exploiting the opportunities arising from the North Sea oil and gas resources to develop local capabilities. In Stavanger these capabilities developed as a result of collaboration and coordination, orchestrated and supported powerfully by the national and local governments. In contrast, in Aberdeen, the past developments are better characterized as market-based, where the most powerful role was played by competition.

The Stavanger story looks in many ways like a textbook case of how to build local innovative capabilities; the Norwegians set 'Norwegianization' as a policy goal and went about its implementation in a systematic and consistent manner. In contrast to the UK experience, the Norwegians were perhaps fortunate that key contextual factors such as macroeconomic conditions were aligned with their policy goals.

Whatever the cause, the result has been that the two regions have developed different innovation systems, with different characteristics and different strengths. Interestingly, these differences in development strategies and innovation systems do not appear to have led to significantly different levels of international competitiveness. Rather, the two regions are competitive in different ways. If Aberdeen appears to have some advantages in terms of operational costs, Stavanger shows its competitiveness in its ability to introduce and use new technologies. In the race to internationalize and export their expertise to other oil provinces, both localities appear similarly successful thus far and have each seen rapid increases in the level of exports in recent years, though Aberdeen leads in overall export volume. Neither region shows significant signs of diversification into other industries. All in all, our measures of 'industrial competitiveness' do not suggest that either region is the clear winner – an interesting and even surprising result, given the significant differences in the underlying local innovation systems.

There are two possible reasons for such a finding. The first is that our measures are simply inadequate to capture performance differences that may in fact exist. The second and, we suspect, more likely explanation is that differences in local innovation systems and practices may be associated with similar performance outcomes over a sustained period. If true, this would add significantly to current understandings of innovation systems. Both possible explanations call for continued close study of the dynamics of local innovation systems.

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