Local Innovation Systems Project

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FROM ‘BLACK GOLD’ TO ‘HUMAN GOLD’

A Comparative Case Study of the Transition from a Resource-Based to a Knowledge Economy in Stavanger and Aberdeen

LIS Working Paper 06-002
July 15, 2006

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A Comparative Case Study of the Transition from a Resource-Based to a Knowledge Economy in Stavanger and Aberdeen[#]

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Executive Summary

This report presents the results of the first phase of a comparative case study of offshore oil and gas industry development in two important regional centers in the North Sea oil province: Stavanger in Norway and Aberdeen in Scotland. The focus of this study is on the capabilities for innovation that have grown up around the oil and gas industry in the two locations. The oil and gas industry is among the most capital and technology-intensive of all industries, and the role of technological innovation in aiding the discovery of economically viable new resources and improving the efficiency of resource extraction is critical. This sector is also one of the most highly globalized of industries. Stavanger and Aberdeen have each benefited from the global stock of industry knowledge and technology, and each has also contributed to it.

The industries in the two locales have much in common, including the geological similarities of the UK and Norwegian continental shelves, and the shared technical challenges of operating in the harsh physical environment of the North Sea. The two regional industries today are broadly similar in structure and scope and comparable in scale, employing roughly the same number of people and comprising comparable numbers of companies, including all the international major oil operators and integrated service companies. The total population of the two regions (Rogaland County, of which Stavanger is the largest municipality, and the county of Aberdeen) are roughly the same, and the oil and gas sector is by far the largest industry in each location. Stavanger and Aberdeen also each served as an important regional economic center prior to the discovery of oil in the 1960s.

Different Development Pathways

Despite these similarities, Stavanger and Aberdeen have followed different paths in exploiting the opportunities for local economic development created by the oil and gas. The Norwegian authorities at the national, regional, and local levels made concerted and sustained efforts to develop local capabilities in the oil and gas sector. Local capability-building efforts in the UK were initially given lower priority, were pursued less consistently, and were not carried as far.

Norwegian government policies included the creation of a national oil company (Statoil), the active use of licensing terms and other measures to promote technology transfer from foreign companies to local organizations, a localization policy that led to the establishment of major governmental institutions including Statoil and the Norwegian Petroleum Directorate in Stavanger, and the development of local higher education and research capabilities. Such policies were instrumental in helping domestic firms in existing industries like construction and shipbuilding to enter the oil and gas industry, as well as helping new local firms to grow and become competitive internationally.

The response of the British government to the emergence of the oil and gas industry in Aberdeen was quite different, in part because of the different historical circumstances that attended its birth. The U.K. oil industry long predated the North Sea oil discoveries, and major international players like BP and Shell had by then amassed great economic power and political influence. The industry already had a political, administrative, and financial center, and it was in London. Moreover, during the key early years of North Sea development the British government was preoccupied with a crippling balance of payments crisis. Among other things, this precipitated the adoption of a rapid oil depletion policy, which required technical inputs that only the American oil service companies were then equipped to provide. The goal of local capability-building was a secondary consideration. The national government later did pursue a 'Buy British' policy through the Offshore Supplies Office (OSO). But the policy was relatively unselective – it did not, for example, distinguish between indigenous firms and subsidiaries of foreign companies – and it did little to strengthen domestic technological capabilities in key fields.

The local authorities in Aberdeen, as in Stavanger, worked hard to attract key industrial players into the region. Both locations became the operational centers of their respective national industries, although the UK industry remained more geographically dispersed than the Norwegian industry, with Stavanger accounting eventually for almost 50% of total oil and gas sector employment, compared with 20% in Aberdeen. While the Stavanger authorities took early action to build new education and research institutions in the region to support the emerging oil and gas industry, there was no systematic effort to develop education and research capabilities in the Aberdeen area. Such capabilities did emerge in Aberdeen as well as elsewhere in the UK, but mainly as a result of initiatives taken by the institutions themselves, or even by individual academics, rather than through planned or coordinated approaches involving the state at any level. In general, the two universities in Aberdeen, whose founding long predated the discovery of oil, were less proactive in developing technical capabilities relevant to the oil industry than their counterparts in Stavanger, which were founded coincident with the establishment of the oil industry in the region, and whose development was directly shaped by it.

Different Innovation Systems

These differences have contributed to the emergence of distinctly different local innovation systems in the two regions. Stavanger has accumulated technological capabilities deliberately and systematically in key institutions, including Statoil, local and national government organizations, domestic and foreign companies, and education and research institutions. Statoil, especially, has played an important role in stimulating local industrial innovation and the development of innovative supplier firms. It has done so as a demanding customer, as a sponsor, and as a broker of information and expertise, and it has promoted technological collaboration between firms in the region. ConocoPhillips and major contractors such as Aker, ABB and Kvaerner have also played significant roles in developing the local innovation system. RF-Rogaland Research and the University of Stavanger have been systematically developed to provide applied research and education capabilities that are tightly linked to the industry.

In Aberdeen, although leading operators like BP were active in developing local technological capabilities for deepwater operations in earlier years, more recently these activities have been scaled back – BP itself has dramatically reduced its R&D activities in Aberdeen – and today there is no leading corporate patron of local innovation in Aberdeen to match Statoil's role in Stavanger. Aberdeen's universities have interacted with the industry more sporadically, and more through the initiative of individual academics than as a result of institutional planning. The smaller, niche companies in Aberdeen generally appear less closely linked to major operators and to local research institutions than their Stavanger counterparts.

Both Stavanger and Aberdeen have attracted the four global integrated oil and gas industry service providers, but – consistent with these patterns – they appear to have done so in somewhat different ways. Stavanger has become the North Sea headquarters of Schlumberger, the most technologically driven of the four, and Schlumberger has established a significant research capability in seismic and reservoir monitoring there. Aberdeen has attracted Weatherford, 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.

In general, the local innovation system in Stavanger has been characterized by relatively high levels of collaboration and coordination among key public and private institutions, with national and local government playing strong supporting and often orchestrating roles, and with strong inputs from local research and educational institutions.

Collaboration and coordination have been less evident in Aberdeen, particularly in the recent past. There, the essential ingredient of local innovation capabilities appears to be a rich and diverse pool of human resources and a flexible local labor market. Many UK nationals were recruited into the global oil and gas industry in and out of Aberdeen, gained significant operational experience abroad and at home, and formed their own companies around ideas they developed through such experience. If there has been a singularly important mechanism for innovation in Aberdeen, it has been the absence of job security or obvious career trajectories.

In sum, observers with experience in both locations have characterized Aberdeen as a ‘business-driven’ and Stavanger as a ‘technology-driven’ center of innovation, and we found considerable evidence to support this.

Performance Outcomes

These differences in innovation systems and approaches have been associated with different patterns of industry performance in the two regions, but not – or at least not yet – decisive differences in overall competitiveness. Aberdeen firms have been exposed to global market forces with relatively little labor protection, and in the boom and bust conditions of the oil industry labor mobility has been greater. Norwegian firms are generally thought to have higher cost structures, partly resulting from safety and labor market regulation and benevolent work schedules. On the other hand, those high cost structures have been a driving force for the adoption of process and organizational innovations such as e-production which are intended to boost productivity and drive down costs. Technology adoption has also been promoted by the technology-oriented Norwegian operators. Both factors have contributed to what is generally regarded as a greater propensity to introduce new technology on the Norwegian continental shelf than on the UK side. On the other hand, the rate of patenting in oil and gas-related fields in Aberdeen has been more than twice as high as in the Stavanger region.

The oil fields in the North Sea province are now reaching the mature phase, production costs are increasing, and there are indications that the attention and resources of the international oil industry are beginning to shift away as economically attractive new oil-producing regions open up elsewhere. Although the offshore oil and gas industry will remain vital to Aberdeen and Stavanger for many years to come, both regions are now contemplating the prospect of a life less dependent on oil and gas. Today, capabilities for innovation in the two regions are mainly being applied to improving the performance of local exploration, development, and production activities, but over time they may also provide a foundation for more sustainable economic development and growth, whether through exports of products and services to other oil and gas-producing regions, or through diversification into different but technologically-related branches of industry.

Exports to the global oil and gas industry from both regions are increasing rapidly, as are sales via overseas subsidiaries. The export performance of the two regions is similar. Aberdeen is in the lead, but by a relatively small margin. To date, neither locality shows much evidence of diversification out of oil and gas into other sectors, though both are beginning to make efforts to develop a new identity as an 'energy' capital, with greater focus on renewable energy.

Taken overall, the measures that were available to us in this study do not indicate that either region is the clear winner in terms of overall industrial competitiveness – an interesting and even surprising result given the significant differences in the character of the innovation systems in the two regions. There are at least three possible reasons for this finding. One is that not enough time has yet elapsed for the full effects of these differences on performance to become visible and measurable. A second possibility is that the simple measures we have used are unable to capture performance differences that already exist. A third possibility is that different innovation systems and practices may be associated with similar performance outcomes over a sustained period.

Relationship to other research

The Stavanger-Aberdeen research presented in this report is part of the Local Innovation Systems (LIS) project, an international research partnership based at the MIT Industrial Performance Center.[*] The LIS research team is studying specific cases of innovation-led industrial transformation in more than 20 locales around the world. The transition occurring in Stavanger and Aberdeen, from a resource-based to a 'knowledge' economy, is one of several types of industrial transformation analyzed in the LIS Project. The findings are contributing to a more comprehensive picture of the roles of universities and public research institutions as creators, receptors, and interpreters of innovations and ideas; as sources of human capital; and as key components of social infrastructure and social capital.

[*] See Richard K. Lester, "Universities, Innovation, and the Competitiveness of Local Economies: A Summary Report from the Local Innovation Systems Project – Phase I", MIT Industrial Performance Center Working Paper 05-010, 13 December 2005 (available at http://web.mit.edu/lis/papers/LIS05-010.pdf.)

1. Contexts

Introduction

This project 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 great debates about globalization that have roiled much of the industrialized world in recent years have typically focused on the role of national governments as instruments for promoting the benefits of globalization or, more often, ameliorating its negative impacts. National governments have frequently found themselves in the firing line as anxious and dissatisfied citizens seek protection against what they see as the depredations of global markets, global capital flows, and the integration into the global economy of huge pools of low-wage labor in the developing world.

In hindsight, the predictions of some early analysts of globalization that national governments would become essentially powerless and irrelevant, at the mercy of rootless global corporations moving productive assets at will across an increasingly ‘borderless’ world economy, have turned out to be exaggerated. Even today it is difficult to find a truly global company; national borders still do matter in economic affairs; and it is much too soon to write the obituary of national governments as players in the global economy, despite the encroachments on their traditional authority in various domains.

But from the perspective of local economic communities, the sense of vulnerability to the forces of globalization is acute, and probably also more warranted. From the local perspective, the rules of the game are indeed set elsewhere. Local communities have fewer resources available to them to cope with the impacts of globalization. Indeed, in many cases local leadership itself has been eroded as the traditional pillars of the local economy – banks, manufacturing firms, law firms, accountants, etc. – have been acquired by large national or multinational organizations with no particular interest in or commitment to the community. For many local communities, the notion of a ‘borderless world’ is uncomfortably close to the truth – certainly their ability to shield themselves from the turbulence of global economic forces is highly circumscribed.

But these communities are not totally without resources to cope with the challenges of globalization. Much of the hard work needed to cope with these challenges – building infrastructure, improving educational performance, strengthening cooperation between public and private institutions – is in fact often better undertaken at the local level than by centralized directives. Local institutions and strategic initiatives may indeed be more suited and coordinated at the local level than the national level. In this project we focus on one such response*: strengthening 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. These activities are essential for productivity growth and for sustaining and improving wage rates, and are themselves typically associated with attractive, well-paying jobs. In advanced economies, especially, the links between innovation, productivity growth and prosperity are increasingly well recognized, and while most of the policy initiatives directed towards improving innovation performance have been taken by national governments, there is increasing attention to this set of issues at the regional and local levels too.[1] Local communities throughout the advanced industrialized world would surely agree with the view recently expressed by one official about the U.S. economy as a whole: "America must never compete in the battle to pay their workers least, and it will take sustained innovation to ensure that we don't have to."[2]

Local innovative capabilities are themselves subject to the pressures of globalization, however. Even regions with significant concentrations of innovative activity today cannot assume that they will be able to hold onto them indefinitely. The range of possibilities here is bracketed by two limiting scenarios. At one end of the spectrum, local companies, recognizing the importance to their own innovation processes of tapping into the global network of knowledge and ideas, reach progressively farther afield to do so, and eventually relocate these activities and perhaps ultimately all of their operations out of the region altogether. At the other end of the spectrum, local companies seek to boost their innovation performance by strengthening their ties with other local firms and with local public research and educational institutions. In this scenario, the local economy emerges as a center of new knowledge creation and application, attracting firms from elsewhere, and stimulating the formation of new local businesses.

The broad goal of this research project is to study the range of possible outcomes delimited by these two scenarios, examine the consequences of the different outcomes for local economic development, and gain insight into the actions, strategies and policies at the local level that are associated with each type of outcome. Ultimately we seek to develop actionable recommendations to local communities directed towards the strengthening of local capabilities for innovation.

Our method of approach in this project is a matched pair comparative case study of the development of the offshore oil and gas industry in two important regional centers of activity in the North Sea oil province: Stavanger in Norway and Aberdeen in Scotland. Stavanger and Aberdeen each began their rise as oil centers following the discovery of major oil resources in the North Sea in the 1960s, and for more than three decades they have both served as important nodes in a far-flung international network of oil exploration, development, production, transportation, processing, and distribution operations that by general agreement is one of the most highly globalized of all

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[1] See Roger Geiger and Creso Sa, "Beyond Technology Transfer: U.S. State Policies to Harness University Research for Economic Development", *Minerva* (2005) 43, 1-21.
[2] Bruce Mehlman, Assistant Secretary of Technology Policy, U.S. Department of Commerce, in testimony before the House of Representatives Committee on Small Business, June 18, 2003, at http://www.technology.gov/Testimony/BPM_030618.htm.

industries. The oil and gas sector[3] is also among the most capital and technology-intensive of industries, and as the world's demand for these fuels continues to rise, and the balance between supply and demand tightens, the role of technological innovation in aiding the discovery of economically viable new resources and improving the efficiency of resource extraction is seen as increasingly critical. Stavanger and Aberdeen have each benefited from the global stock of industry knowledge and technology, and each has also contributed to it. But while the world's oil and gas industry will continue to expand for many years to come, for any particular center of exploration and production – including Stavanger and Aberdeen – the long-term prospect is more ephemeral. Oil and gas resources in the North Sea province will deplete before the world as a whole 'runs out' of these fuels in any meaningful sense, and the key question for Stavanger and Aberdeen centers not on how the world will negotiate the transition to the post-hydrocarbon era, but rather on how these communities themselves will be able to maintain their prosperity and growth once oil and gas production in the North Sea begins to decline. In this research project our focus is on the capabilities for innovation that have grown up around the oil and gas industry in each location and the role that these capabilities have already played and will continue to play in that transition.

1.1.1. The Local Innovation Systems Project

The Stavanger-Aberdeen research we are reporting on here is part of a larger project, the Local Innovation Systems (LIS) project, in which an international team of researchers based at the MIT Industrial Performance Center is studying specific examples of industrial transformation in more than 20 locales around the world. The current portfolio of case studies in the LIS Project is shown in Table 1-1. As with Stavanger and Aberdeen, the basic unit of analysis in all these studies is an innovation-driven or innovation-assisted transformation in the mix of products and services produced in a specific industry in the locale in question. Industrial transformation is obviously a continuing process rather than a one-time event, but for analytical purposes we have chosen in each case to focus on events and processes taking place during a specific time interval. The starting point for the LIS Project is that the economic success of a region depends on the ability of the firms in that region to adapt to new market and technological opportunities. Thus, in each of these studies we seek to understand the processes that lead to changes over time in the mix of products and services that are produced within a particular industry in that locale. We are particularly interested in the local capacity to develop and/or to absorb new technologies, and we seek to understand the factors and processes that account for differences in outcomes in this regard. We have a special interest in the contributions made by universities and other public research institutions to these processes.

[3] Though there are important differences in the technologies and markets for oil and gas, many enterprises, especially at the upstream stages, are involved in both.

Table 1-1: LIS research portfolio

Current LIS Research Portfolio		
Country	**Location**	**Industry/technology**
USA	Rochester , NY	Opto-electronics
USA	Akron , OH ,	Advanced polymers
USA	Allentown , PA	Opto-electronics/steel
USA	Boston , MA	Bioinformatics
USA	New Haven , CT	Biotechnology
USA	Charlotte , NC	Motor sports (NASCAR)
USA	Greenville-Spartanburg , SC	Autos
USA	Alfred-Corning	Ceramics
USA	Youngstown , OH	Steel/autos
Finland	Tampere	Industrial machinery
Finland	Turku	Biotechnology
Finland	Seinajoki	Industrial automation
Finland	Pori	Industrial automation
Finland	Helsinki	Wireless
Finland	Oulu	Medical Instruments
UK	Central Scotland	Opto-electronics
UK	Aberdeen	Oil and gas
UK	Cambridge	Bioinformatics
Taiwan	Taipei-Hsinchu	Electronics
Taiwan	Taipei-Hsinchu	Software
Japan	Hamamatsu	Opto-electronics
Japan	Kyoto	Electronics
Norway	Stavanger	Oil and gas

Of course, local innovation processes may only be one of a number of important contributors to the industrial transformations we are studying. So a necessary element of each of the LIS studies is to place these local innovation processes in the context of other, broader changes that may be taking place in the industry at that time.

The principal mode of data collection in the LIS studies is in-depth interviews with firms, university researchers and administrators, and national and local economic development officials and policymakers, using semi-structured questionnaires. Drawing primarily on the interviews, and augmented by quantitative analysis using local and regional business and economic databases as well as patent and publication data as appropriate, we have sought to trace the scientific and industrial development of the industrial field, and to analyze and compare these histories in different locations.

1.1.2. Oil and Gas Development in the North Sea Province

The transformation of interest in the current project has been referred to in another context as a shift from 'black gold' to 'human gold'. [4] Regions blessed with an initial endowment of hydrocarbon wealth in the ground seek to develop a local capability for wealth creation that can be sustained beyond the economic lifetime of the oil and gas resource. How can such regions negotiate the transition from a resource-based to a 'knowledge' economy by developing and sustaining an industrial base that is less dependent on their natural resources? How can they convert natural resources to other kinds of assets capable of sustaining economic prosperity after the resources have been depleted – that is, financial capital, human capital, social capital, and knowledge assets? What are the policies, strategies, and practices that enable such regions to gain greater or lesser benefits from their natural resources in this regard? These are especially timely questions to consider in the context of the North Sea province, where oil and gas production in the UK appears to have peaked and Norway may be just a few years behind.

For oil and gas-rich regions there are, in principle, two main routes to achieving such a transition. The first is essentially *exogenous* to the oil and gas industry itself. In this scenario, financial capital accumulated locally from the exploitation of the energy resource is used to acquire physical or financial assets in knowledge-intensive sectors that are unrelated technically to the oil and gas industry. The second route – and the one we are interested in here – is *endogenous* to the oil and gas industry. After the initial discoveries of hydrocarbon resources, and the arrival of international oil companies, the host region becomes connected to a technologically-advanced industrial network that is global in reach. Although the host region is initially only an outpost of this global network, it will attract technological know-how from elsewhere, and it may also be able to draw on relevant local knowledge resources. Initially this accumulated knowledge will be applied to improving the organizational and/or the technological performance of local exploration, development, and production activities, but in due course it may also provide a foundation for more sustainable economic development and growth in the region, whether through exports of products or services to other oil and gas-producing regions, or through diversification into different but technologically-related fields of industry.

In the current project we have studied this transition in two regional centers of the North Sea oil and gas industry: Stavanger, on the southwest coast of Norway, and Aberdeen, in northeast Scotland. For nearly forty years, since the initial discoveries of oil in the North Sea, Stavanger and Aberdeen and their surrounding regions have been at the center of offshore oil and gas industry development in Norway and the UK respectively. The oil fields in the North Sea province are now maturing, production costs are increasing, and the attention and resources of the international oil industry are to some extent shifting away as economically attractive new oil-producing regions open up in other parts of the world. Although the oil and gas industry will remain vital to the economies of Aberdeen

[4] *Economist*, 13 August 2005, p. 19.

and Stavanger for many years to come, both regions are now contemplating the prospect of life after the reserves have been depleted.

Even a superficial comparison points to many similarities between the two locales, including their physical proximity (Aberdeen and Stavanger are roughly 230 miles apart); the geological similarities of the UK and Norwegian continental shelves; and the shared technical challenges of operating in the harsh physical environment of the North Sea.

Aberdeen and Stavanger each served as an important regional center of economic activity prior to the discovery of oil (fishing, granite quarrying, etc. in the case of Aberdeen, shipbuilding, agriculture, and the canning industry in Stavanger). The oil and gas industries developed over roughly the same time period in the two locations. And the industries today are comparable in size (see Table 1-2). In both locations several hundred companies are participating in the industry, and a significant number of companies – including all the international major oil operators and integrated service companies – are represented in each center. Employment in the oil and gas sector is about 37,000 in Rogaland County, of which Stavanger is the largest municipality, and about 39,000 in Aberdeen (Aberdeen City and Aberdeenshire). The total populations of the two counties are also similar. In each region oil and gas is by far the largest industry, and in each case too the local industry accounts for an important share of national employment in the sector.

Table 1-2: The Oil and Gas Industry Clusters in Stavanger and Aberdeen (2003)

	Population (densely populated area/ region)	Employment in O&G-cluster's core	Total employment in O&G-cluster	Number of companies in O&G-cluster
Aberdeen	210,000/ 440,000	27,000¤	39,000	900-1000
Stavanger	200,000/ 393,000	26,000#	37,000	500-600

¤: includes engineering and construction (2001)
#: of which is oil companies: 10.000 (Aetat 2001)

As we will see in more detail shortly, there are also significant differences between the two regions. Whereas nearly 50% of Norway's total employment in the oil and gas industry is concentrated in Stavanger, only about 20% of the UK oil and gas industry employment is located in Aberdeen. The oil and gas industry also plays a much larger role in the Norwegian national economy than it does in the UK, accounting for 20% of the gross domestic product, 25% of total investment, and nearly half of all export revenues. [5] By contrast, the oil and gas sector in the UK accounted for 2.5% of the gross domestic product of the UK in 2003.

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[5] Norwegian Oil Industry Association, "Global Industry with Regional Significance: Social Perspectives", July 2005.

There are physical differences as well. The oil fields on the Norwegian continental shelf are on average several times larger than their U.K. counterparts, and total proven and probable reserves of oil and gas are respectively twice and almost four times larger on the Norwegian side. Oil production on the Norwegian side peaked several years later than it did on the U.K. shelf, and Norwegian North Sea gas production is not expected to peak until the end of the decade, compared with the peak U.K. output year of 2002.

But the many technical, economic, and demographic similarities between Stavanger and Aberdeen make it easier to evaluate the significance of the differences between them, and to explore in a systematic way their causes and/or consequences. In particular, the similarities between the two regions facilitate our comparative analysis of the capabilities for innovation in each region, and how these capabilities have affected the development of the oil and gas industry in each case.

In the next section we present the conceptual framework for this analysis.

Analytical framework

Recent studies of globalization at the MIT Industrial Performance Center and elsewhere have highlighted three interrelated changes in the global economy: (1) the growth of worldwide production networks; (2) the growing fragmentation or 'deverticalization' of the production process; and (3) a new pattern of geographical industrial clustering, in which activities at the same or adjacent stages in the value chain are located close to each other.[7] These findings point to the need for modifications or extensions to the theory of industrial 'clusters' popularized by Michael Porter, with its logic of agglomeration and industrial specialization at the regional level.[8] They suggest that it is time to shift away from thinking about regions or locales in terms of more or less self-contained clusters of economic activity, and towards the idea of regions as globally connected 'hubs'[9], in which firms – and individuals – are continually making choices about whether to move their assets and capabilities elsewhere and whether to acquire assets and capabilities from elsewhere. The economic development problem in the era of globalization is thus only partly about the internal components, structures, relationships, and processes that are emphasized in descriptions of how clusters operate. It is also about the connections of the region to geographically-dispersed economic networks. From this perspective, local or regional economic communities are embedded in a complex economic fabric; they can be thought of as nodes in three interrelated flow networks – the flow of goods and services; the flow of people; and the flow of ideas and information. Each of these networks is constantly evolving, and part of the challenge facing local communities is to understand the structure of these networks, the forces that are changing them, and their own position within them. As Duke University's Gary Gereffi and Tim Sturgeon of the Industrial Performance Center have noted, "hubs are open to the full force of the global economy, both positive and negative, in ways that clusters are not. Hubs learn faster and more broadly, but experience the turmoil of globalization more acutely than places that are less well connected to global value chains."[10]

The findings about globalization which have led to this revised view of local economic development grew out of studies of manufacturing industries such as electronics, motor vehicles, and textile and apparel. But they are no less applicable to the oil industry. Indeed, while the changes they refer to occurred relatively recently in manufacturing industries, they have long characterized the oil industry. The chain of operations linking oil reservoirs to end users of gasoline or petrochemical products has been global in scope for decades. Also, although the vertically integrated majors continue to be dominant players in the industry, important roles are played at each stage of the chain of value-added by specialist firms, focusing on one or a small number of operations. Third, the oil industry has long been characterized not only by the spatial separation of functions, but also by the clustering of activities of the same type. This is most obviously true of exploration, development and production – where geology forces firms into physical

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[7] See Berger 2005, Arndt and Kierzkowski 2001; Feenstra 1998; Gereffi 1994; Sturgeon 2002.
[8] For a recent critique, see Cassidy, Davis, Arthurs, and Wolfe 2005.
[9] Gereffi and Sturgeon 2004.
[10] Gereffi and Sturgeon 2004.

proximity. But it is also true at downstream stages of the value chain (e.g., petrochemicals manufacturing in Houston, New Jersey, New Orleans, etc.) In short, beyond the lessons to be learned for the oil and gas industry itself, this industry provides a useful model for studying the general problem of local economic development in a globalizing economy, in which the relationship of local activities to global production networks must be considered along with the 'clustering' processes occurring within the locale in question.

Our research in Stavanger and Aberdeen suggests that this 'local-global' relationship develops according to a fairly predictable pattern, consisting of the following processes:

Localization: In the earliest stages of development, after the first discoveries of oil are made, multinational oil companies move into the region. Initially this presence lacks permanence, but over time at least some of these companies begin to put down local roots. Housing is provided for their expatriate employees, local authorities arrange for schooling for their children, and the companies establish training programs for new local employees. These companies also bring in know-how, equipment, and technology from elsewhere to assist in exploration and production activities. International service providers, often with long term relations with operators, also arrive. Local companies seek out opportunities to enter the industry, often drawing on native capabilities that can be adapted to the needs of the newly arrived firms. 'Infant industry' policies may contribute to the localization process.

Upgrading/Deepening: In the next phase of development, specialized knowledge and technology still flow into the region, but local industrial capabilities begin to develop, and over time more of the products and services required by the industry are developed and supplied within the region itself, whether by the local operations of multinational firms or by firms of local origin. Likely candidates for early local development efforts are products and services designed to meet requirements that are unique to the region. Also during this phase, local colleges and universities may develop specialized curricula to support the needs of the local industry, and may also begin to provide research, development or testing services to local firms or multinationals. Finally, new locally-based firms offering specialized products or services may emerge during this period, whether as spinouts from multinationals or from local universities or research institutions, or as wholly-new startups.

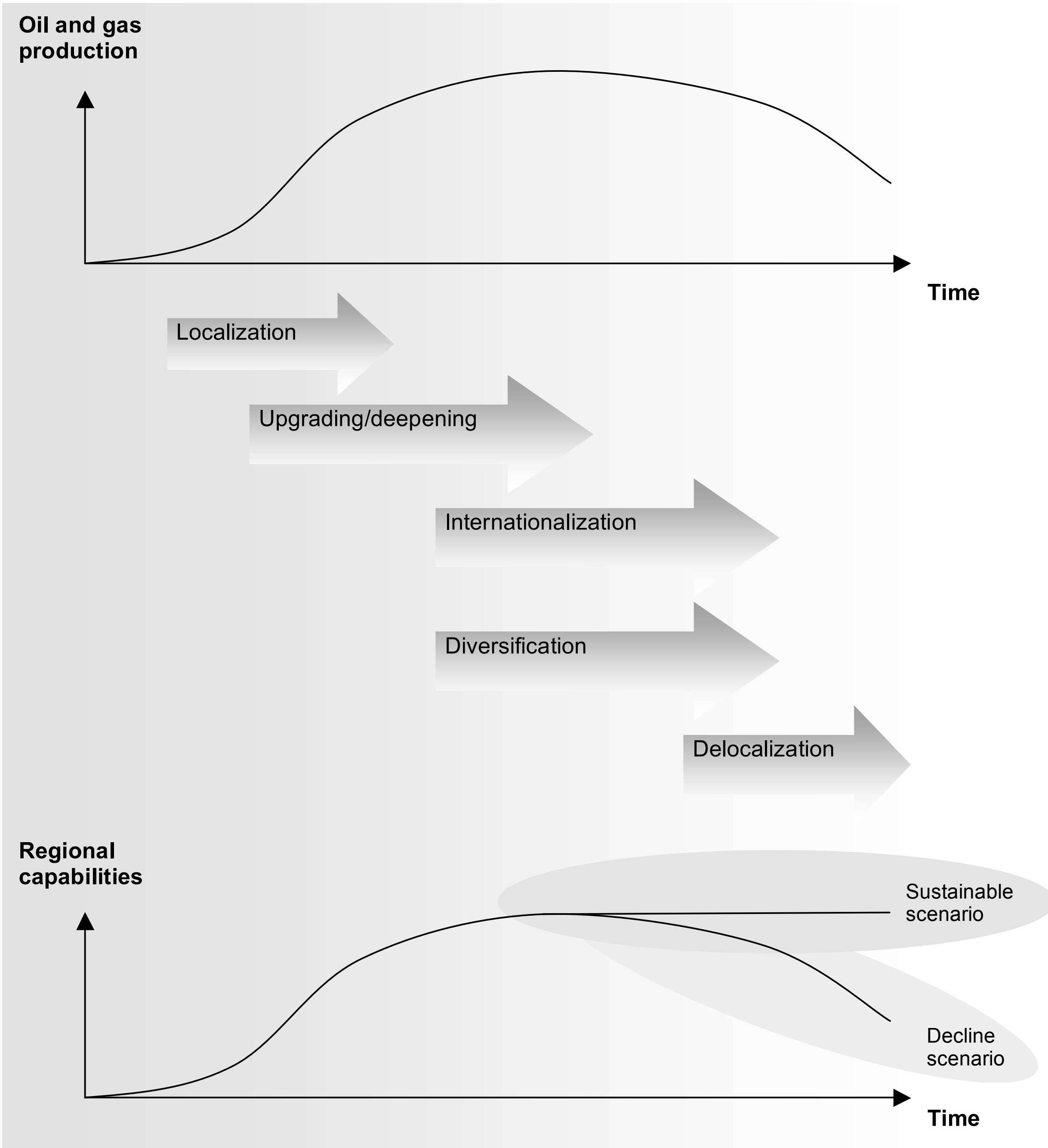
Internationalization. At this stage, locally-based firms develop cost, technology or other advantages enabling them to compete effectively with non-local rivals in third-party markets, and begin exporting products and services to other oil and gas producing regions.

Diversification. Drawing on technological and market knowledge accumulated from their oil and gas operations, local firms may in due course diversify into different industries, or, alternatively, into downstream operations in the oil and gas industry such as refining, petrochemicals production, gas-to-liquids conversation, and so on.

Delocalization. Eventually, the local industry may begin to lose critical mass, especially as local resource depletion continues. International firms redeploy key people and other locally-based resources to other, more attractive locations where discovery, development, and extraction can be achieved at lower cost. Capable local firms are bought up and their assets relocated by international players. Other local firms may simply go out of business as local demands decline.

This is a stylized description, and not all of these developmental stages or processes necessarily occur in every center of oil production. As we shall see, not all of them have yet occurred in Stavanger and Aberdeen. Nor should these processes be assumed to occur in rigid sequence; often, in fact, they overlap with each other. But generally we might expect to find a progression along this cycle over time, and that this progression is at least loosely correlated with the cycle of resource exploitation in the region (see the schematic in Figure 1-1). The upper part of the figure refers to the development cycle of oil and gas resources. The lower part refers to regional industrial and technological capabilities. Two possibilities are indicated. In the 'decline' scenario the regional capabilities dry up in parallel with the physical resources; as companies relocate their production activities to more productive regions the region loses its knowledge resources. By contrast, in the 'sustainable' scenario the local oil industry transforms itself into a knowledge intensive industry which continues to develop beyond the lifespan of the natural resources.

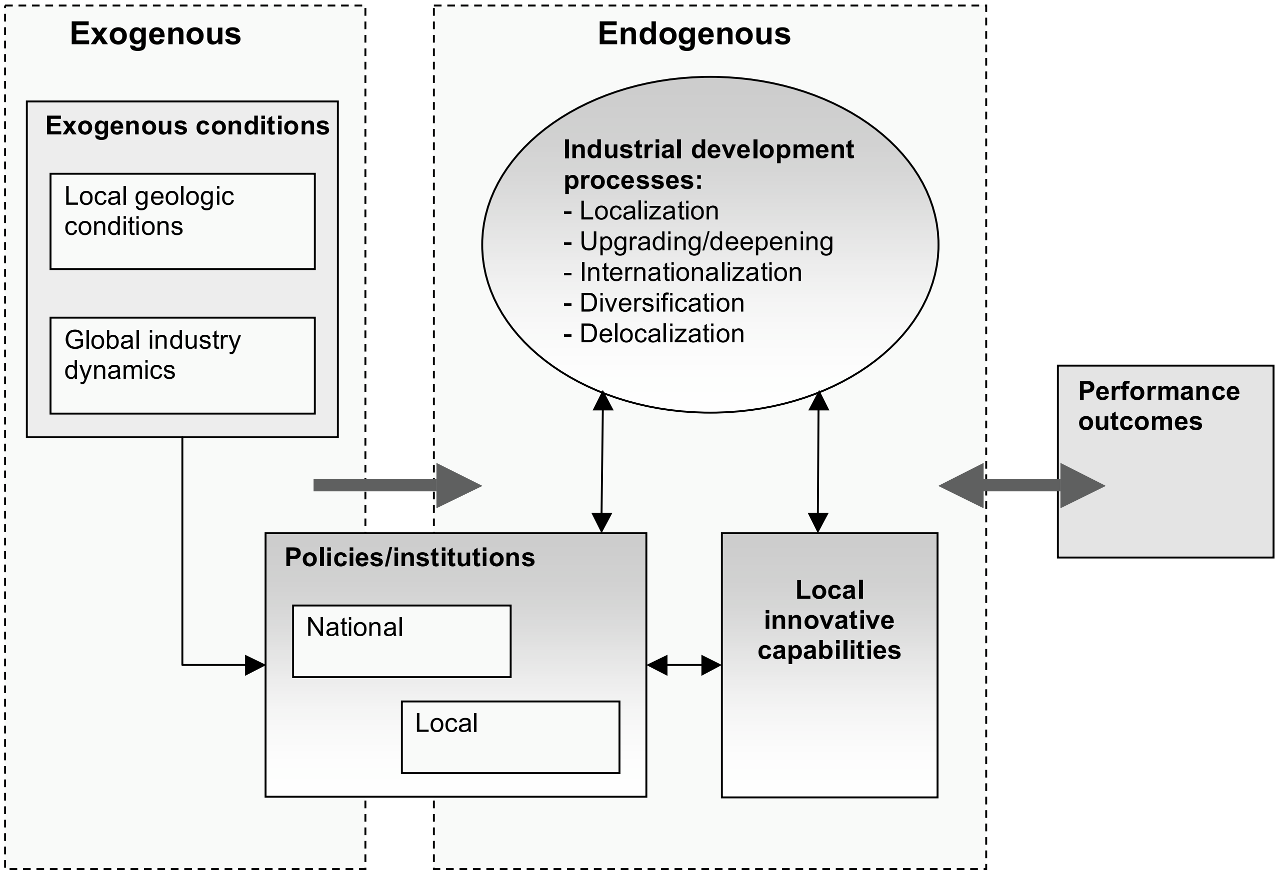
Figure 1-1: A Stylized Description of the Industrial Development Process in Oil and Gas Producing Regions



We further expect that in any given region the intensity, extent, and timing of subsequent industrial development processes will be affected by the capabilities for innovation that exist in the region at that stage. Thus, for example, the prospects for upgrading/deepening, internationalization, and diversification in a region should each be correlated with the presence of local innovative capabilities of particular kinds.

In this report we compare the development of the oil and gas industry in Stavanger and Aberdeen along this cycle. Our purpose is to explore the differences in local innovative capabilities between the two regions, to understand how these differences arose, and to examine the effect of these differences on the industrial development pathway followed in each region. We organize our findings according to the process model depicted in Figure 1-2. The core of the model is the cycle of industrial development processes described above. The progress of each developmental process both influences and is influenced by the capabilities for innovation that are present in the region at that time. And this relationship is in turn affected by various ‘drivers’, including national and local policies and institutions. These interactions are at the core of the local/regional innovation system. The system is also affected by local geologic conditions and by developments in the industry that are external to the region (‘global industry dynamics’ such as geopolitical shifts, wars, global environmental factors, and so on.). (In our matched pair comparison, these exogenous factors are to a first approximation common to both regions.) Finally, the status of the regional innovation system can be assessed at any given time in terms of a set of performance outcomes. Knowledge of those outcomes can in turn be expected to influence the future development of the innovation system.

Figure 1-2: The regional innovation process



The rest of this report is organized as follows:

Section 1.3 describes the research methods we used. In Section 2, an overview of the North Sea province is provided, including a short description of the two regions' oil and gas industry structure. Section 3 presents a 'snapshot' of the performance of the two regions. Section 4 describes the 'exogenous' conditions bearing on the two regions, including local geological conditions and developments in the global oil and gas industry. Section 5 describes national and regional policies and institutions in Norway and the UK. In Section 6 local capabilities for innovation present in both industry and higher education and research are described. Section 7 continues this discussion with an detailed analysis of patenting behavior in the two regions. Finally, the cycle of industrial development processes in the two regions are described and analyzed in Section 8. The report ends with discussions and conclusions.

Research methods

We used a comparative case study methodology to carry out this research. The approach is inspired by the method of similarity (Skocpol and Somers 1980). The underlying concept is to conduct a structured comparison of two cases which are similar in all aspects except for the target phenomenon which is to be explained. In theory, the use of a matched pair allows analysts to move from a single idiosyncratic and isolated case to a more generalizable causal story. In practice, there are no cases that satisfy such rigorous conditions since there are many dimensions of difference which cannot be controlled. As such, the main benefit of comparison is not so much to enhance the generalizability of findings as 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 used a combination of archival data, including quantitative data such as statistics, patents and publication patterns; secondary materials; and interview data. Our study involved four levels of analysis: individual, organizational, local, and industrial. While our principal interest was to draw implications for the two localities, both our data and explanatory factors arose at all levels. Care had to be taken to ensure consistency in making inferences. For instance, individuals interviewed may have limited organizational perspectives depending on their positions and experience. In order to understand organizational perspectives, it was important to seek out both organizational accounts such as organizational reports or interviews with organizational leaders, as well as some individual member accounts for triangulation. Similarly, secondary materials such as publicly available statistics, reports and prior research on the regional or industrial level would describe local or industrial phenomena, without reference to organizational members. In order to secure internal validity, inferences made in such materials were triangulated against findings from organizational data.

We carried out 31 interviews in Stavanger and 40 in Aberdeen. The 31 Stavanger interviews were conducted with 29 key informants; with 14 people representing industry, 1 from government, 7 from research institutions, 4 from university, and 3 people representing industry related organizations. In addition, an expert panel of key informants was established to support the researchers in the data interpretation phase. In Aberdeen 40 interviews were conducted with 40 key informants; with 17 people representing industry (3 from operators, 4 from large contractors, 8 from small niche companies, and 2 from financial organizations); 8 from governments (3 from UK, 3 from Scottish and 2 from local governments); 9 people from three universities; and 6 from other industry related organizations.

The interviewees were identified in a cascading manner through interviews which started with key personnel at local government and industry organizations.

2. Overview of the North Sea Province

In the late 1950s very few people believed that the North Sea district might contain rich oil and gas deposits. However, the discovery of gas at Groningen in the Netherlands in 1959 caused geologists to revise their thinking on the region's petroleum potential. Exploration activity started in the mid 1960s and agreements on dividing the North Sea in accordance with the median line principle were reached by Norway and UK in March 1965. However, it was not until the Forties (UK) and Ekofisk (Norway) fields were discovered in the late 1960's that the first real signs of an emerging offshore petroleum industry began to emerge.

The regions centering on Stavanger, Norway and Aberdeen, Scotland (UK), located on opposite sides of the North Sea (see map below), have become the leading centers of oil and gas-related activity in the two countries. Even though both countries have oil and gas activities in other areas, the North Sea was the first, became the largest, and remains the most important oil province for each country.

Figure 2-1: The two locations

The Norwegian Continental Shelf (NCS) and the United Kingdom Continental Shelf (UKCS) are neighbouring shelves, divided only by a median line. The shelves share many of the same challenges, including similar geology and a harsh physical environment.

Stavanger is located on the southwest coast of Norway and is the main city of Rogaland County. When we refer to the Stavanger region, we refer to the greater city region comprising 14 of the 27 municipalities in the county[11]. However, for data and comparative reasons, we will sometimes refer to the whole of Rogaland County[12].

[11] These 14 municipalities count for approximately 67% of Rogaland County's total population.
[12] Norway has a two tier-system of local government: the municipalities and the county authorities. There are 434 municipalities and 19 county authorities in Norway.

Aberdeen is located on the north-east coast of Scotland. When we refer to the Aberdeen region, we mean the county of Aberdeenshire, centrally including the city of Aberdeen.

The two regions are comparable in many ways. Aberdeen and Stavanger developed their oil industries over similar periods, starting in the late 1960's, and have been exposed to many of the same global industrial dynamics. Both regions are integrated in advanced economies and share the same proximity to the North Sea. Their role as national oil and gas centers is also very similar – both regions claim to be the oil capital of Europe. In other words, both regions have succeeded in turning their natural oil and gas resources into regional industrial clusters,.

Aberdeen and Stavanger – General Comparison

The two regions have similar populations. The Aberdeen region is home to just over 430,000 people (less than 1% of the UK population), while Rogaland County houses 390,000 people (about 8.5% of the Norwegian population).

In area coverage, the Aberdeen region is 6,501 sq km, accounting for 8% of Scotland's territory. Rogaland County, at 9,325 sq km, accounts for less than 3% of Norway's land.

The Aberdeen region employed 230,000 people in 2003, or about 53% of the total population. The unemployment rate, at 4.6% for Aberdeen City, Aberdeenshire and North East Moray in 2003, was lower than the overall UK rate of 5.0% and well below the Scottish rate of 5.8%.[14] The Stavanger region (Rogaland County) employed 190,000 people in 2003, accounting for 50% of the region's population. In that year, the unemployment rate was 3.8%, just below the Norwegian average of 4.0%.

The structure of employment in the two regions is shown in Table 2-1. The breakdowns are broadly similar. The biggest difference is the higher share of public sector employees in Stavanger. In general, Norway has a larger share of public employees than the UK, and by Norwegian standards, the greater Stavanger region has a relatively low share of public employment.

[14] Source: Eurostat: Unemployment rates at NUTS level 3

Table 2-1: Industry of employment (2001)

Industry of employment	Aberdeen-region	Stavanger-region
Public administration, defence, education, health and social work	23.0%	30.6%
Recovery of crude oil and natural gas, manufacturing, mining and quarrying	18.8%	21.3%
Wholesale, retail trade, hotels and catering	20.2%	17.5%
Financial services, business activities, real estate	15.5%	13.1%
Construction, power and water supply	7.9%	6.9%
Transport and communication	6.6%	5.7%
Agriculture, forestry and fishing	3.5%	4.2%
Other	4.4%	0.7%

Although the share of oil and gas employment in the two regions was quite similar in 2001, the time trends have differed somewhat. Aberdeen has experienced a gradual decline in oil and gas employment from a peak of 56,000 in the early 1990s to 39,000 in 2003. Oil and gas employment in Stavanger increased steadily during the 1990s and reached a peak of 45,000 in 1998/99, fell dramatically to 33,000 in 2000, in tandem with the oil price, and then rose again, to 37,000 in 2003.

In 2001 Aberdeen accounted for 23% of the UK's total oil and gas employment, while Stavanger accounted for 48% of Norway's. These shares have been stable over time and indicate stronger geographic clustering of the oil and gas industry in Norway than in the UK.

Fact box: Stavanger

Rogaland County is one of Norway's leading industrial areas. The county is known for being the centre for oil and gas recovery in the North Sea and houses a wide range of oil and gas related industry. Rogaland is also Norway's largest agriculture county, measured in both value creation and man-labour year. The county is also Norway's largest fish-food producer and houses the most-reciveing fishing port in the country. There has been great development within fish farming and export of framed fish and mussels is increasing rapidly. The service industry has experienced a rapid growth and the county holds torusim as one of its future priority areas.

The county consists of 27 communes in total and a population of 393,000. This constitute 8.5% of Norway's total population.

Rogaland County extends to 9,325 sq km, representing 2.9% of Norway's total territory

Stavanger big-city region comprises 13 of the communes in Rogaland County; Stavanger, Sandnes, Randaberg, Sola, Finnøy, Rennesøy, Kvitsøy, Klepp, Time, Hå, Forsand, Strand, Hjelmeland, and Gjesdal. The total population in this region is 264,830.

Stavanger City is Rogaland County's largest city and administration centre. The population in the city 114,000.

Fact box: Aberdeen

Aberdeenshire is a predominantly rural area in the North East of Scotland. Traditionally, it has been economically dependent upon the primary sector (agriculture, fishing, and forestry) and related processing industries. Within the last 30 years, the emergence of the oil and gas industry and the development of the service sector have broadened Aberdeenshire's economic base, leading to rapid population growth.

Aberdeenshire extends to 6,313 sq km (2,437 square miles), representing 8% of Scotland's overall territory. The landscape varies from mountainous Cairngorms, through rich agricultural lowlands to rugged coastline.

Aberdeenshire has a population of 226,940 (2001), representing 4.5% of Scotland's total, and a 20% increase since 1981, 50% since 1971. The population has a higher proportion of younger age groups than the rest of Scotland, reflecting employment-driven in-migration in recent decades.

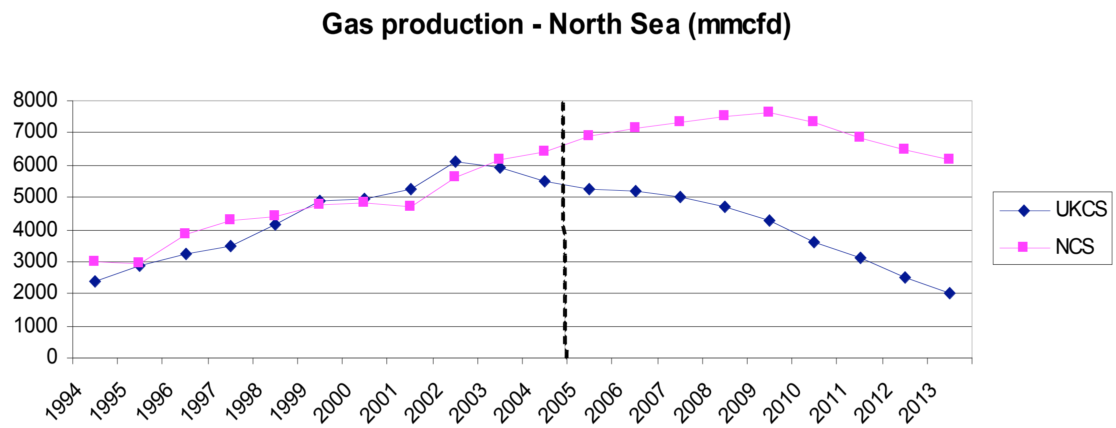
Aberdeen City is the home to a population of 212,125. Covering an area of 184.47 square kilometres (71.22 square miles), the Granite City owes its distinctive appearance to the locally quarried and widely exported, building material.

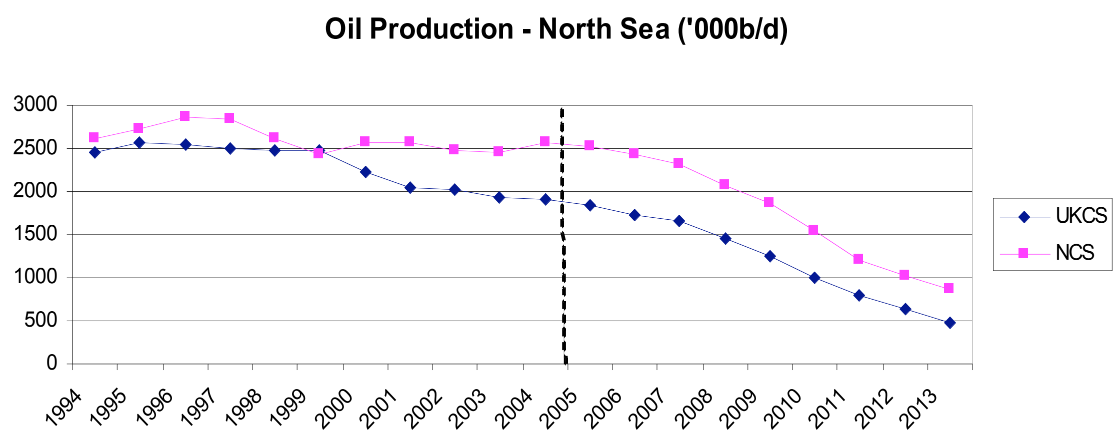
NCS and UKCS – Resource comparison

Although the two shelves are located in the same province, they also differ in some respects. First, the average size of discovered fields differs significantly. The discoveries on the NCS have been fewer but larger in size. Through 2002, approximately 200 fields were discovered on the NCS, with a cumulative production of 60 billion barrels of oil equivalent (o.e.). On the UKCS 450 fields were discovered during the same period, with a cumulative production of 50 billion barrels o.e. Between 1998 and 2002, the average field size of discoveries on the NCS was 209 million barrels o.e., and 49 million barrels o.e. on the UKCS.

Second, the UK's oil and gas production has been gradually declining in recent years. Oil production peaked in 1999 and gas production in 2002. Norwegian oil production has been quite stable but is expected to reach its peak in 2006. Gas production in Norway is on the rise and is expected to peak in 2010 (See Figure 2-2).

Figure 2-2: Oil and gas production – North Sea area only (Source: Wood Mackenzie)[15][16]





Norway's proven and probable reserves of oil and gas are respectively almost twice and more than three times as large as UK reserves (see Table 2-2).

Table 2-2: Reserves as of 31st December 2004 (proven and probable)[17]

Reserves (proven and probable)	UKCS	NCS
Oil (million barrels of oil equivalent)	6135	10233
Gas (billion Sm^3)	826	2676

[15] From 2005 to 2013 are estimations made by Wood Mackenzie
[16] Abbreviations:
mmcfd = million cubic feet per day
b/d = barrels per day
[17] Information was gathered from NPD in Norway and DTI in UK.

Most estimates suggest that the UKCS is 5-10 years ahead of the NCS in maturity. This is in line with the numbers above and is also the general view expressed by our interviewees.

The oil and gas industry in Stavanger and Aberdeen

The industrial structures of the two regions are subtly different. Aberdeen has a greater total number of companies, estimated at 900-1000[18] compared with 500-600[20] in Stavanger (Aberdeen City Council 2001; Cumbers 2000; Frontline Mgmt Consultants 2000; Jakobsen et al. 2000; Leknes and Steineke 2001; MacKinnon et al. 2001; Trends Business Research 2001; BI 2003)[21]. The composition of industry is also different, with Aberdeen having a greater diversity of operators and specialized service companies (see Table 2-3). This has important implications for the two regions' innovative capabilities, as will be discussed in Section 6.

Table 2-3: Industry composition in Stavanger and Aberdeen

	Stavanger	**Aberdeen**
Total	500-600	900-1000
Operators and licensees	39 (NCS)	116 (UKCS)
Integrated service providers	4	4
Service/suppliers/contractors (from SMEs and main contractors)	450-550	800-900

[18] McKinnon et al 2001 in their survey of SMES in 2000, identified a total of 1027 firms in Aberdeen area (including Stonehaven, Inverurie, Peterhead) including 73 large firms with more than 500 employees.

[20] A mapping of the oil and gas industry in Norway by BI in 2003 identified a total of 457 oil and gas suppliers and 43 oil companies in Rogaland county.

[21] The estimates emerge as means from a wide range of national 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 that are set in order to be defined as part of the cluster, and which geographical parts of the two regions that 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.

2.3.1. Operators

Operators are the key players in the industry because they have direct control over the fields. Operators may play a critical role in technological innovation either by sponsoring technology development financially or through their roles as technology users and demanding customers. For the two localities, the contributions of operators can be examined at two levels: which operators are active on the NCS and UKCS irrespective of their presence in the two localities; and which ones have also become local players within the two localities.

2.3.1.1. Operators on the two shelves

All the major international oil companies are represented in both UK and Norway (ENI, Total, Chevron, ConocoPhillips, BP, Statoil, ExxonMobil and Shell). However, the number of medium-sized integrated oil companies, independent oil companies[22] and other licensees[23] differs considerably. By the end of 2005, 39 companies were current equity holders and participants in production licenses on the NCS. Of these, 24 had operator status. By April 2006, a total of 116 companies were registered as licensee equity holders on the UKCS. Altogether, the UKCS has almost three times as many licensees as the NCS.

These differences derive partly from differences in licensing strategies, and partly from changing operator interests given field conditions. The NCS has traditionally been characterized by projects that are few in number, large in size and resource-intensive, with very substantial assets to be realized.

The UK was quicker to introduce licensing terms that were attractive to new and smaller entrants – given that the focus of most international majors was clearly moving away from mature shelves in the UKCS to more promising areas elsewhere. Since 2003 licensing strategies in the NCS have also changed and greater numbers of smaller companies have been introduced. As of 1 January 2005, 25 new companies had pre-qualified for or become licensees on the NCS, and another ten companies had expressed interest (NPD; Facts 2005). A majority of the new entrants on the NCS are already active on the UKCS, but Norwegian-owned independent companies like the greenfield company Revus Energy have also joined in.

Today, non-major companies control 40% of the reserves on the UKCS, while 60% belongs to the majors. On the Norwegian side, non-majors (excluding Norsk Hydro) hold only 4% of the reserves. Further, three players, Statoil, Norsk Hydro and Petoro (SDFI),

[22] An independent oil company is an oil producing company which is not integrated forward into downstream activities. It only focuses on upstream activities.
[23] Other licensees are non-oil companies with licensees

together own 66% of the reserves on the NCS, and with the rest of the majors owning 22%.[24] In contrast, BP, ExxonMobil and Shell, the three dominant actors on the UKCS, own only 44% of the reserves there.

2.3.1.2. Operators in the two localities

The operators have differing presences in the two localities. Whereas for most operators on the NCS Stavanger has become the obvious choice for their Norwegian headquarters, Aberdeen has more often been only an operational centre for operators whose main UK offices remain in London.

Stavanger developed in the early 1970's as a national centre for Norway's oil and gas activities. Of all the operators and licensees with interests on the NCS, 80% have offices in Norway, and of these, 70% are headquartered in Stavanger. In addition, Stavanger is the global headquarters for Statoil, one of the major international oil companies. In addition, ConocoPhillips has located its largest non-US unit in Stavanger. The new entrants are also locating in Stavanger, even though most of the future offshore activity in Norway is expected to take place further north. Being part of the industrial cluster is evidently an important factor in making localization decisions.

Aberdeen, in contrast, developed as an operational centre, with most operators maintaining their headquarters in London, close to the licensing office of the Department of Energy (DOE) or Department of Trade and Industry (DTI). Indeed, Aberdeen was regarded as a classic 'branch plant economy', dominated by branch units of large companies whose headquarters were elsewhere (Hallwood 1986). In the 1990s, concerns over high costs pushed oil operators to rationalize and restructure their own operations (which resulted in 20% decrease in employment in the 10 largest operators in the UK), as well as their contractual relationships (Cumbers and Martin 2001). This was also a period of consolidation through mergers and acquisitions. It was in this context that some of the operators (as well as major contractors) moved their headquarters to Aberdeen (Cumbers 2000; Cumbers and Martin 2001). For instance, Conoco moved its UK HQ from London in 1993; BP Exploration moved its European decision-making from London and Glasgow to Aberdeen, and AMOCO moved its UK operational HQ from London to Aberdeen. Even so, in 1997 only 14 out of the 38 oil companies (38%) that were registered as operators in the UK had permanent offices in Aberdeen (Leitch 1997), and none of the smaller UK oil companies had their HQs there (Cumbers and Martin 2001).

There are also important differences in the make-up of mid-cap and independent operators. Aberdeen has many more of these operators than Stavanger, primarily because, with oil fields that are generally smaller and older, Aberdeen is at present a more attractive setting for smaller operators with particular capabilities for producing in brownfields.

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[24] Petero is a state-owned corporation acting on behalf of the state and responsible for the state's direct financial interest (SDFI).

2.3.2. Main contractors

Main contractors are companies operating in the MMO market (maintenance, modification and operation) and EPCI market (engineering, procurement, construction and installation). In addition, project management, process systems, equipment and subsea systems are often part of their offerings to the industry. These companies are important partly because they typically engage a large number of smaller, often regionally based suppliers. Also, through the integrated EPCI contracts, they develop capabilities to coordinate large projects.

Traditionally, the oil operators in both oil provinces themselves managed multiple decontractors. This practice changed in the 1990s as integrated contracting emerged as a result of collective efforts to reduce costs under the Cost Reduction in New Era (CRINE) initiative in the UK and the NORSOK initiative in Norway. In Norway, integrated EPCI contracts were introduced in 1994 and changed the relationship between oil companies and contractors. In addition, as the need to remove old and outdated offshore installations has increased, the major contractors are today including decommissioning in their services.

The shift to larger, all-encompassing contracts has resulted in major consolidations in this segment. Today, the offshore development market on both sides of the North Sea is dominated by a handful of major contractors who market themselves as capable of carrying out total enterprise contracts; e.g from concept development to offshore installation and start up. In addition to a few super-majors within this segment, there is a range of mid size contractors that are more specialized. In order to compete with the majors, these tend to team up in alliances, and in doing so are capable of taking on larger EPCI contracts.

In Norway, this segment is dominated by major actors such as Aker Kvaerner and Vetco Aibel, with mid size contractors such as Bjørge, Sørco and Fabricom in the next tier. Aker Kvaerner is a Norwegian company headquartered in Oslo with subsidiaries all over the world. Its MMO subsidiary, Aker Kværner Offshore Partners, is located in Stavanger (5500 employees in Norway). Vetco Aibel is a subsidiary of Vetco International Ltd. and was bought out from ABB. It is headquartered in Oslo with several operational divisions in Norway and internationally. Vetco Aibel's largest operational division within the MMO market is located in the Stavanger region.

In Norway, the main contractor segment has gone through major consolidation over the last decade. One example is the merger between Aker and Kvaerner which led to the establishment of Norway's largest industrial conglomerate. Another example is the mid-tier company Fabricom. It is headquartered in Stavanger and is fully owned by the French industrial conglomerate Suez. Since 2000, Fabricom has expanded its capabilities through the acquisition of companies such as AMEC's Norwegian subsidiary AMEC Process

Energy, Kellog Brown & Root's Norwegian subsidiary and Halliburton's fabrication unit Haliburton KBR, and today Fabricom is challenging the leading MMO contractors.

In UK, the main contractor segment is dominated by four actors; Aker Kvaerner, the Wood Group, AMEC and Vetco Aibel. The Wood Group, based in Aberdeen, grew from a local fishing and ship repairing operation (Wood, 1983), and is today celebrated as the only local Aberdeen company that has developed into a global company (Cumbers 2000). Aker Kvaerner is represented in the UK through its subsidiaries, and is expanding there. Its MMO unit in the UK is headquartered in Aberdeen. However, Aker Kvaerner is not considered as an EPCI contractor in the UK. AMEC is a diversified international construction company, headquartered in London, whose offshore division is based in the North East of England (Cumbers 1994). Vetco Aibel UK is headquartered in Petersfield.

These companies have a complex corporate history of mergers and acquisitions of various local capabilities, and it is difficult to summarize what they represent in terms of local interests today.

2.3.3. Integrated service companies

The integrated service companies are a small group of global firms that were established in the 1920's. Through numerous mergers and acquisitions, they emerged in the 1980s as integrated suppliers of technology and services, and today constitute the core of the industry's innovation system. They plan, develop and produce technology and services based on the identified needs of the oil companies, and compete on being at the forefront of technological development. They are large enough to have significant R&D investments and are also known for their acquisitions of innovative small companies in both regions. This segment of the industry is still dominated by US companies. Their global R&D strategies are of importance when trying to understand the innovation dynamics of the industry.

In Norway, the three American majors Schlumberger, Baker Hughes and Halliburton are considered the super-majors within the oil and gas service industry. In the Stavanger region these companies have 1650, 900 and 1000 employees, respectively. These three firms are also active in the UK, along with a fourth company, Weatherford, which is considered a super-major in the UK but not – despite its presence there – in Norway.

The four companies have chosen to locate their North Sea headquarters differently. Weatherford and Baker Hughes have their regional North Sea headquarters in Aberdeen whilst Schlumberger has located its HQ in Stavanger. Halliburton has chosen not to establish a regional head office – it is viewed as being equally present on both sides.

Schlumberger, Baker Hughes and Halliburton compete on developing and delivering technology to the operators. They all carry out some sort of locally driven R&D. This may be in local laboratories or R&D units, or through the process of interacting with customers locally. However, they each centralize some of their R&D activities at technology centers. Schlumberger has two main research centers in Ridgefield, Connecticut (currently in the process of relocating to Boston, Massachusetts) and Cambridge, England. In addition, the company has specialized research satellites in Stavanger, Moscow, and Dhahran (Saudi Arabia). Schlumberger's research and technology centre in Norway (distributed between Oslo and Stavanger) focuses on seismic and reservoir monitoring, and invests NOK 530 million annually in R&D, which is 12-13% of Schlumberger's global R&D budget.

Baker Hughes has located its technology centres in Houston (US) and Celle (Germany). Halliburton's R&D activity is spread around the world. Its largest technology centre is in Oklahoma, followed by two major ones in Houston and Canada. Weatherford's global research headquarters is in Houston, but it also has a test and research capacity in Aberdeen covering areas such as downhole technology, well intervention, well screen, offshore well services, drilling and well services (DWS), completion and production systems (CPS) and expandable sand screen. Weatherford is considered to be less technology-intensive and more limited in its range of services than the three other enterprises.

2.3.4. Service/supplier industry

The oil and gas industry in both Stavanger and Aberdeen includes a vast range of small and mid-sized service/supplier companies. In both regions, some of these SMEs are innovative niche companies that provide technological innovations to operators and the integrated service companies. In each location, technological innovations are described as occurring through partnerships between user/operators, major contractors and small niche companies.

There were 457 such companies in the Stavanger-region in 2003 (BI report, 2003), generating annual sales of about NOK 29 billion in 2001. This segment employs more than 21,300 people in the Stavanger region, compared with approximately 15,000 people employed by the operators. The median supplier in the Stavanger-region generated sales of NOK 5.3 mill in 2001, and the largest supplier NOK 3.5 bill.

In Aberdeen, the total number of companies in the oil supply industry, excluding major contractors is about 800-900[25] [26]. A 2000 survey of SMEs (defined as those with less than 500 employees) found that over 75% of these were small companies with less than 50 employees (Cumbers et al 2003).

[25] Subtracting 30-40 or so operators and 15-20 large contractors from the total estimated number of companies of 900-1000. This is roughly of the same as MacKinnon, Chapman, and Cumber's estimate for SMEs with employment less than 500 in Aberdeen area including Stonehaven, Inverurie, Peterhead is about 800 (MacKinnon et al 2001 a.b).

[26] There are no official statistics for outputs of SME in Aberdeen. UKOOA estimated that oil and gas's contribution to the UK GDP was 23 billion pounds in 2003, comprising 2.5% of the total (UKOOA 2004).

Similarities and differences: Why a Stavanger-Aberdeen comparison makes sense

Stavanger and Aberdeen developed into major oil and gas industry centers as a result of their proximity to the new fields in the North Sea and the learning capabilities of the two regions. There are striking parallels in timing as well as physical conditions. The two regions developed during the same period, working with the same set of global oil and gas industry companies, and facing the same set of technological and market conditions. In both cases the fields were in a deepwater setting and had to be developed in the harsh environment of the North Sea. Even though there were important differences in field size – a point to which we will return – the technological challenges faced by the two regions were strikingly similar, particularly when compared with other oil provinces.

And yet there were also important differences in the policies concerning the development of the industry. In Norway, the central government immediately took charge of the situation and developed a set of hands-on policies to manage the process of oil industry development. In the early phase of development key locational decisions were made to concentrate industry-related institutions in Stavanger. Special attention was also given to the development of domestic technological capabilities.

In the UK, in contrast, the central government was not nearly as concerned either with the development of an indigenous oil and gas industry or with the idea of concentrating industry-related capabilities in a given location. It is fair to say that Aberdeen emerged as an oil capital in spite of the central government's locational policies. Technology policies were also much less focused in the UK, and tended to change over time.

These similarities and differences provide a unique opportunity for comparing the two regions. They provide a kind of natural experiment for examining the effects of policies, particularly with respect to the development of capabilities to innovate.

3. Comparisons of performance outcomes

What are the key differences between Stavanger and Aberdeen in their ability to compete in the global economy? What capabilities have they developed that will affect their economic prospects when production of oil and gas begins to decline? The main purpose of this section is to provide a performance snapshot of the two regions – to clarify the main differences in the capabilities of the two regions.

The starting point for understanding the capabilities of the two regions is to consider two dimensions of competitive performance: **costs and technological innovation**. Many interviewees on both sides speculated about differences between the two regions along these dimensions; Stavanger was thought to have developed technology-oriented competitiveness, while Aberdeen's industry was associated with operational and business efficiency – most notably in its ability to maintain low costs. The truth of these claims is explored in the following sections.

Second, the potential sustainability of local capabilities is examined by considering **export performance** and **diversification into other sectors**. These aspects will become increasingly important as oilfields in both regions gradually become less attractive. UKCS reached the peak of oil production in 1999, and companies in Aberdeen therefore need to be looking to overseas markets if they are to continue to grow. Stavanger has a somewhat longer time horizon as the NCS is not expected to reach its peak of combined oil and gas production until 2008 (NPD, Resource Report, 2005). Given these differences, we might expect Aberdeen companies to be further along in the process of diversifying into new markets, either through exporting to other oil provinces or by entering new sectors.

Third, we consider the loss of capabilities from the two regions, either through companies exiting of their own accord or being relocated following acquisitions.

Operating cost comparisons

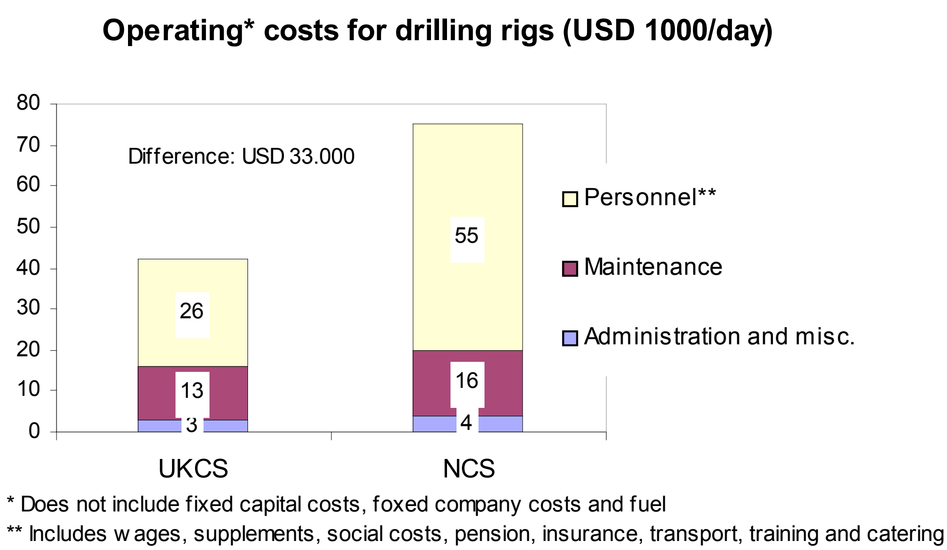
Many interviewees as well as some previous industry studies indicated that Norwegian companies have a higher cost structure than their UK counterparts. The main reason is the higher labor costs in Norway, which in turn arise from more stringent personnel practices and labor market regulation.

Compared with the UKCS, the cost level for operation and maintenance of platforms on comparable fields on the NCS is about 10 percent higher (Kon-Kraft, 2004). The most important reasons are the wage costs for offshore labor on the NCS, combined with higher manning levels.

For many years, the UK and Norwegian shelves have functioned as two separate rig markets, and surplus and available rigs on the UKCS are rarely used on the NCS. They are instead used in other offshore regions or are laid up, even though Norwegian rig rates are generally considerably higher for comparable rigs. The explanation lies in regulatory differences between the Norwegian and UK shelves. Rigs operating on the UK shelf do not meet Norwegian regulatory requirements and the expense of upgrading is too great (Kon-Kraft 2004).

Drilling and well costs are especially important for the development of small fields, where these costs can account for half of the total development costs. The high Norwegian operating costs for drilling rigs primarily reflect higher personnel costs on the NCS. This difference amounts to approximately USD 30,000 per day for a typical third or fourth generation drilling rig with the same size crew (See Figure 3-1). The basic wages for a drilling crew are approximately the same in Norway and the UK. But shorter Norwegian working hours, various wage supplements, social costs and travel expenses add up to a substantial difference, for drilling from both floaters and fixed installations.

Figure 3-1: Operating costs for drilling rigs (Kon-Kraft 2004)



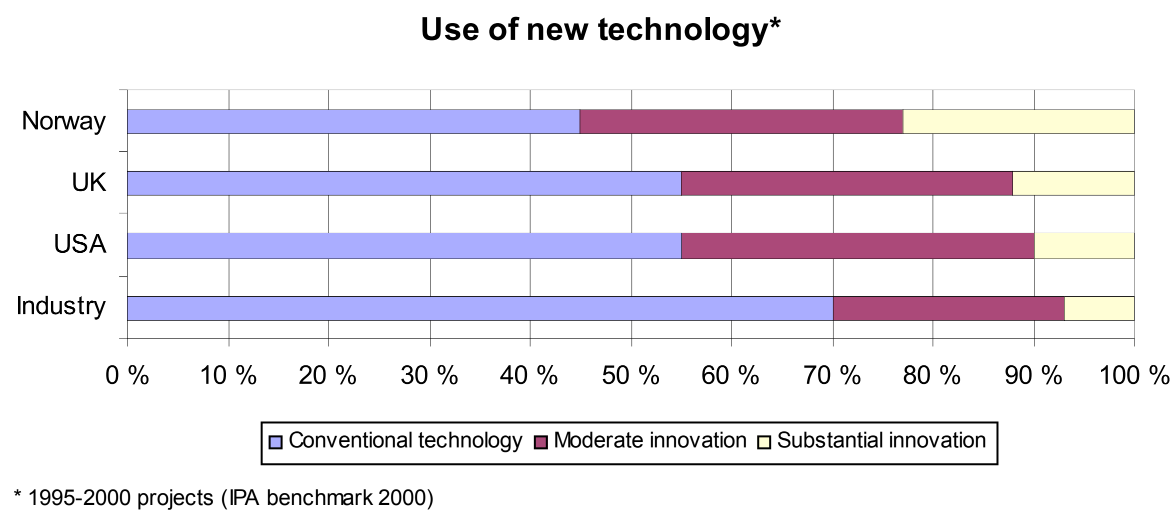
Innovation comparisons

3.2.1. Use of new technology

Interviewees as well as at least one prior industry study indicated that there may be a greater propensity to introduce new technology on the NCS than in either the UK or the US – largely owing to the dominance of technology-oriented operators such as the Norwegian companies Statoil and Norsk Hydro.

Independent Project Assessment (IPA) performed a benchmarking study on the use of technology and innovation in the global oil and gas markets in 2001 (Duncan, 2001). The study concluded that Norway is world leader when it comes to the use of new technology for facilities (see Figure 3-2.). This was also suggested by interview data. The IPA study did not comment on the relation between the use and the development of new technology. The NCS is often referred to as a test-bed for new technology, suggesting that companies from all over the world test technology there.

Figure 3-2: Use of new technology (Duncan 2001)



3.2.2. *Patenting*

The rate of patenting, a frequently-used indicator of technological inventiveness, also provides interesting insights into the two regions. As shown in

Table 3-1, a total of 756 patents involving at least one Aberdeen-based inventor have been granted by the U.S. patent office, compared with 307 patents involving at least one Stavanger-based inventor. In both countries, the rate of patenting grew from a low base in the 1970s and 1980s to a significant level in the 1990s. A detailed analysis of patenting behavior in the two regions is presented in Section 7.

Table 3-1: Distribution of patents by inventor (all US patents through June 2005)

	No. of Patents
With at least one Aberdeen-based inventor	756
With at least one Stavanger-based inventor	307

Source: US patent database

Comparison of export performance/orientation

Direct exports from Scotland into the global oil and gas industry by service/supply companies were valued at € 2.36 billion in 2003, a sharp rise of 39% from € 1.45 billion in 2001 (SCDI, 2004). This continues an upward trend in exports, whose share of total oil-related turnover rose from 5% to 20% between 1985 and 1995 (Aberdeen City Council/Aberdeenshire Council as in Cumbers 1996). In addition, it is estimated that a further € 2.63 billion of revenues were generated in 2003 by businesses based overseas but ultimately reporting to a Scottish HQ. This has grown substantially from € 1.3 billion in 2000 and indicates a trend of Scottish companies setting up locations in key overseas markets. Taken as a whole, the Scottish service/supply base generated € 5 billion in international sales in 2003.

In a sample survey of oil and gas-related SMEs in the Aberdeen area conducted in 2000, more than two thirds of the respondents indicated that they had moved into new export markets in the last 5 years, and nearly 60% reported entry into a new sector over the same period (Chapman et al. 2004). However, the shares of turnover in such activities are still low. Only 23% of the companies reported their export sector share to be above 40%. Nonetheless, there is a basic awareness among firms about the need to diversify, whether geographically or sectorally.

Service/supply companies in Norway averaged 39% of their petro-related sales to foreign customers in 2003. Over time, this share has increased considerably, indicating that service/supply companies with an industrial base in Norway increasingly compete beyond the NCS (Kristiansen et al., 2004). The majority of these firms have registered sales abroad. In fact 90% of the sales in the petro-oriented Norwegian industry are accounted for by firms that sell both in Norway and abroad. Foreign sales were estimated at € 4,3 bill in 2003. Somewhat less than 50% of these sales are direct exports.

In both Scotland and Norway; total international activity is increasing, and so is sales via overseas subsidiaries. In dollar terms[27], foreign sales amounted to USD 6 billion for Scottish service/supply companies and USD 5.1 billion for Norwegian service/supply companies in 2003.

3.3.1. Market

The main market for Scottish oil and gas service and supply companies is North America, which accounted for some 26% of total international sales in 2003 (SCDI, 2005). Sales to the region are increasingly dominated by subsidiary operations. The European market (EU, other Western Europe and Eastern Europe) accounted for 16.5% of total international sales in 2003 with Norway (4.1%) being the most significant market, closely followed by Russia (4%). The Norwegian market has shown a fall in value from € 266m in 2002 to € 205m in 2003 and it also appears that an increasing level of Norwegian activity is being carried out via the establishment of subsidiaries as opposed to direct exports. In terms of direct exports, Norway was the principal market until 2003, when this position was taken over by Russia. The scope of international activity was wider than ever in 2003, with subsidiary sales activity reported in 37 countries compared with 25 in 2002. Direct exports to 83 markets were recorded in 2003, compared with 66 in 2002.

For Norway, the UK is still the most significant market, although its importance has been declining (from a 35% share in 2001 to 24% in 2003.) The US is the second most important market with a 22% share. South Asia/Australia has increased its share from 16% in 2001 to 21% in . Emerging markets for Norwegian oil and gas industry exporters are Brazil/Venezuela (from 3% to 10%) and Angola/Nigeria (from 5% to 12%). In addition, the level of activity in Russia is expected to increase as a result of ongoing operations in the far north.

In sum, the export volumes of the industries in the two localities are similar. Aberdeen leads, but by a small margin that could easily be erased within a short interval, and that is probably not significant given the 5-10 year difference in field maturity between the UKCS and NCS. More significant may be the broader range international markets served by the Aberdeen exporters.

Comparison of diversification efforts

The North Sea oil and gas industry has enjoyed almost three decades of development and growth, but it is widely accepted that as the shelves mature, market opportunities are now decreasing compared to other oil provinces. However, opportunities to sustain local capabilities obtained through oil and gas industry development are now discussed on both sides. One of these is diversification into related new product and service markets –

[27] Exchange rate per 31. December 2003

especially in the field of renewable energy. In both regions, too, efforts are underway to sequester carbon dioxide in depleted offshore gas reservoirs.

In a survey conducted in 2000 among SMEs in Aberdeen, only 10% of the companies reported diversification into non-oil sectors accounting for more than 40% of turnover. Comparable data are not available for Norway.

There are clear signs of an emerging focus on renewable energy in Aberdeen, with oil-related companies both large and small beginning to announce new activities. A pioneering effort by Talisman, a Canadian oil operator, in partnership with Scottish and Southern Energy (SSE) is a good example. These companies began collaborating in 2002, and in 2004 announced a 24 million pound project to demonstrate the world's first deepwater wind energy turbines. A local forum on renewable energy, bringing together representatives from government, industry and universities, was established in 2000. Scottish Enterprise recently located one of its flagship technology institutes, the Intermediary Technology Institute, Energy (ITIE), in Aberdeen.

The Stavanger region is also experiencing an increase in activities related to alternative energy sources like wind, solar, and wave power. Norsk Hydro is experimenting with small-scale wind turbine driven hydrogen production. The wind generates electrical power, which in turn produces hydrogen which is used in fuel cells. Normally, households obtain their electricity from the turbines. On non-windy days they are supplied by the fuel cells. Statoil will open a hydrogen filling station in August 2006, enabling enthusiasts to drive from Stavanger to Oslo on hydrogen. In addition to these experimental projects by established oil companies, green field companies and established companies from other industries (e.g., utilities) have also entered the scene. In fact, with oil and gas activity in the region still at a high level, local companies have not generally seen the need to diversify. When the oil and gas supply sector experiences a decrease in the demand for its products and services, these firms may be more likely to do so. However, these examples and our interviews in Stavanger indicate that the general mentality is changing from an oil and gas focus to an energy focus.

Outcomes of outmigration and acquisitions

There are strong perceptions, at least in Aberdeen, that there is a significant difference between Norway and UK in the pattern of corporate mergers and acquisitions. Whereas Norway has produced a number of sizable companies, there are few UK equivalents. In Norway Statoil, Norsk Hydro, Aker Kvaerner, Smedvig, and Prosafe have all had a significant history of successful and less fortunate acquisitions – including Aberdeen-based and other UK companies such as Trafalgar House or Consafe. The only significant company on the UK side that grew through acquisition in a similar manner is the Wood Group, whose target acquisitions have principally been US companies, as well as the recent buyout of the British firm Vetco.

Several interviewees in Aberdeen expressed concern about acquisitions, particularly by foreign firms, of innovative local companies. There is a fear that small innovative companies bought up by global companies gradually lose their innovativeness as they become subjugated to the rigid superstructures of the acquiring firms.

Acquisitions of this type have also occurred in Stavanger. However, there appears to be less concern about the negative impact of these foreign buyouts in Stavanger, perhaps because of salient examples whose outcomes have been positive – at least so far. One example is that of GECO, arguably one of the most innovative companies in Stavanger, which specialized in seismic capability. As one interviewee noted, “GECO was the leader on the seismic side. It was bought up in the late 80s by Schlumberger. But that didn’t matter; the centre of expertise is still here.” Under the Schlumberger umbrella, the company has grown from 16 to 250 employees.

In sum, acquisitions are taking place in both regions, but their overall consequences for local capabilities are unclear. The acquiring companies have different strategies, and mergers may lead either to an expansion and upgrading of knowledge or to the reverse.

Concluding remarks: Key differences in ‘performance outcomes’ between Stavanger and Aberdeen

Our structured comparisons suggest that the two localities may be developing international competitiveness at roughly the same rate, but in different ways. The export records of the two localities are not significantly different. Aberdeen leads in volume terms but only by a margin that could erased within a couple of years – not a significant difference given both the growth rate and the maturity difference of 5-10 years between the UKCS and NCS. To date, neither locality shows evidence of significant diversification from oil and gas into other sectors, though much more proactive efforts are beginning to be made. For instance, both regions are trying to move from being oil capitals to becoming energy capitals – with greater emphasis on renewable energy.

The international competitiveness of the two regions may be predicated upon different strengths. Norwegian companies are reputed to have high cost structures, partly resulting from protected and regulated domestic markets, particularly the labor markets, which could pose a significant problem in competing internationally. On the other hand, high cost structures are a driving force for process and organizational innovations such as e-production, designed to drive down the costs and boost productivity.[28] Aberdeen companies have been much exposed to global market forces with very little labor protection, with bust and boom dynamics leading to significant labor mobility. This is due to very different general labor market policies in the two countries. The picture is also differentiated by the fact that wages for Norwegian researchers are relatively low.

[28] E-production (integrated operations/smart operations) refers to the use of ICT-based solutions, including real-time data, to integrate work processes across disciplines and organizations. It enables onshore control and management of offshore operations – regardless of physical distance and geological conditions.

On the other hand, Norwegian companies continue to benefit from proximity to ‘technology-friendly’ users such as Statoil and Norsk Hydro, which have developed a technology culture that is rare in other operators today. The fact that the UK is the main destination for Norwegian exports (and that Norway was the largest destination for Aberdeen’s exports until recently) is also consistent with this picture of the two regions developing different strengths.

The story of Aberdeen as ‘business-driven’ and Stavanger as ‘technology-driven’ centers of innovation was repeatedly told across the two localities by many observers with experience in both locations. Technologists in Stavanger told this story with considerable pride. Technologists in Aberdeen recalled with nostalgia the ‘old days’ when Aberdeen was also technology-driven – referring to the period in the 1980s and early 1990s when Aberdeen was at the cutting edge of new technology.

Finally, while Stavanger appears to be more active than Aberdeen in adopting new technology, it is not as obviously a location where new invention occurs – at least as measured by the patent statistics. This observation underlines the difference between an invention and an innovation. The latter term assumes that the invention actually is implemented and in use.

4. Exogenous conditions

In Section 3 we described differences in the current economic performance of Stavanger and Aberdeen. The next two sections examine how such differences arose.

In this section we discuss two exogenous conditions that helped to shape regional economic performance: (a) the **global dynamics** of the oil and gas industry; and (b) **the physical and geological condition** of the oilfields. These are conditions that individual countries or regions can do very little about. What they can do, in a differentiated way, is to understand and exploit these conditions. In Section 5 we explore a number of endogenous influences on performance, including national and local policies and institutions.

Global industry dynamics

When the North Sea resources were discovered in the late 1960s, the oil and gas industry was already a global industry, dominated by established American companies. The so-called seven sisters, the group of leading global oil companies, included five American firms, together with Shell and BP. The US was the only country with a full range of oil industry firms, from large operators to smaller independent oil companies. The US also had a wide range of supplier companies, from large-scale contractors and service companies to small companies with specialized services and products (Cameron 1986). US companies had significant experience in the shallow water oilfields of the Gulf of Mexico, and they were seen to be the most obvious source of expertise for the North Sea, although that experience later turned out to have less relevance to the harsh conditions of the North Sea than originally expected.

The authorities in Norway and the UK each faced the challenge of how best to harness the expertise of the global (largely American) oil industry to meet their national interests. Both authorities knew from the outset that the interest of global oil and gas companies in the North Sea fields would wax and wane as the attractiveness of these fields relative to other oil provinces changed over time. This has in fact turned out to be the case. New provinces have emerged, and perceptions of profitability have shifted. The disintegration of the Soviet Union and the partial privatization of the Russian oil industry, the emergence of new opportunities such as the deepwater areas of the Gulf of Mexico, and offshore Brazil and Angola, and the maturing of the North Sea shelves themselves have all had a bearing on the level of interest of the major oil companies and the structure of the industry in the region. Since the late 1980s there has been little expectation of further larger field discoveries on the UKCS, and in subsequent UK licensing rounds it has been increasingly difficult to attract large operators. In Norway the strong state participation has had to be balanced with the interests of the international companies.

In the region as a whole, as the international majors have reduced their level of activity, smaller foreign operators have entered the market, and local independents have also been established.

4.1.1. Global policy environment

Government policies can also affect the relative attractiveness of a given oil province. Since at least the 1960s there has been a tendency for oil producing countries to adopt policies specifically designed to promote local technological and industrial capabilities. Too restrictive a set of policies can raise entry barriers and make the oil province unattractive in comparison with other countries. The North Sea presented an interesting case as it was the first time that developed countries had faced the challenge of having to grapple with localization policies.

But it is also important to remember that national and local governments do not have full autonomy in their policy choices. European Union regulations (and specific objections raised by Brussels) have had an important impact on British policies, limiting their ability to promote local capacity building, and with the creation of the European Union in 1992, the operations of the OSO were scaled back considerably. Even Norway, which has remained outside the EU, has experienced growing pressure to conform to EU standards, especially since the mid 1990s. The US government has also raised objections when they have seen unfair practices against their own companies, and this too has had an inhibiting effect on local capability building.

4.1.2. Global consolidation

Mergers and acquisitions have been a normal part of business in the oil and gas industry since the days of Rockefeller's Standard Oil. However, the rate of consolidation appeared to have increased since the oil prices collapsed in 1986, initially among contractors and service companies, and subsequently among majors.

Examples included the merger of Baker with Hughes Tool and Weatherford's acquisition of a large number of companies, small and large (Simmons 2003). Schlumberger has continuously bought niche technology developers. The wave of consolidation among contractors continued well into the 1990s, and was encouraged by the growing tendency of operators to employ larger integrated contracts as a way of reducing costs and increasing contracting efficiencies. Whereas operators used to have a large number of small contracts, large EPCI contracts are now the norm, spanning engineering, procurement, construction and implementation. Today, the oil supply industry is dominated by a few global contractors and service companies.

There continue to be a large number of specialist service and manufacturing companies, most of them fairly small, but the services of these specialist suppliers are increasingly procured by large global contractors, rather than by oil operators directly.

Since 1997 there has been another wave of consolidation, this time involving the majors. BP merged with AMOCO, Exxon with Mobil, Conoco with Phillips, Total with Fina and Elf, and Chevron with Texaco, leading to what has been called ‘the era of mega majors’ (Simmons, 2003). In Norway, the privately owned Norwegian company Saga was taken over by Statoil and Norsk Hydro.

4.1.3. Oil prices

Oil price shocks have been a key influence on the oil and gas industry globally. There have been several price shocks in recent decades. Oil prices rose sharply in 1974 and again in 1979, driven by coordinated cuts in production by OPEC nations.[29] Prices then dropped dramatically in 1986, leading to global crisis for the oil industry. Prices dipped again in 1998, but have risen dramatically since 2004, this time prompted by rising demand outstripping supply.

Oil prices influence the oil and gas industry in a number of ways. First, prices can change the perceptions of the industry in host countries. The oil price hikes in the 1970s undoubtedly changed perceptions of the contribution the oil industry could make to the economies of oil producing countries.

Second, higher oil prices stimulate larger investments in producing fields in order to increase the recovery rate and extend the field life through tail-end investments. High prices also tend to enhance the viability of small or difficult fields in the eyes of oil companies. Conversely, the fall in oil prices during the late 1990s was probably a disincentive for large operators to continue operating in dwindling fields of UKCS.

Third, low oil prices can lead to significant pressures for cost reduction for the industry as a whole – as was the case in the late 1980s and 1990s. The results in this case included a major change in supply relationships, with consolidated contracts and consolidation in industry structure. Cost-reducing process and product innovations tend to be implemented more vigorously in periods of low oil prices, while the willingness to invest in R&D tends to increase with the oil price. In other words, inventions may be developed to prototypes in “good times”, and implemented in less benevolent periods.

Finally, expectations of long term high oil prices will stimulate efforts to find substitutes for oil, including renewable energy, nuclear power, and coal.

Local geologic conditions

The harsh weather conditions and deep water setting of the North Sea oilfields limited the applicability of technical know-how obtained from other oil provinces. New technologies

[29] OPEC, the Organization of Petroleum Exporting Nations

had to be developed to cope with the particular conditions of the North Sea. The huge fields, particularly on the NCS, combined with the deep water and rugged conditions called for very expensive real estate and infrastructure in the form of huge concrete storage and drilling platforms, the Condeep concept. These huge concrete platforms are not easily moved, creating incentives to develop long-reaching horizontal wells, and world records in horizontal drilling lengths have repeatedly have been set in these large fields. In contrast, rigs operating on smaller fields are more mobile, and traditional vertical drilling is thus more cost effective. In recent years, *subsea technology* has been used to increase the recovery of oil and gas. These subsea installations are tied back to the existing offshore infrastructure. This necessitates so-called multiphase flow measurement, the continuous and real-time measurement of flows of water, gas and oil from a well.

There are two key differences between the NCS and UKCS with respect to geology. Norwegian fields are generally larger, and the UKCS is reaching maturity faster. Larger fields and/or higher production rates yield important differences in the unit cost of production, which is typically lower for the NCS. Today, unit costs are approximately 8% lower on the NCS than on the UKCS (Kon-Kraft, 2004). However, fields on the NCS are maturing rapidly, and selected Norwegian fields report that production costs have increased at a rate of 3% per year between 1997 and 2004, compared with 0.4% in the UK. Unit costs are more than double that in the Gulf of Mexico, and remaining globally competitive is an increasing issue for both shelves.

5. Policies and institutions

The previous section examined exogenous factors and conditions that have influenced local capabilities and industrial development processes in Stavanger and Aberdeen. In this section we consider the impact of national and local policies and institutions – factors that are at least partly endogenously determined (see Figure 1-2.) As we shall see, there are significant differences between the two localities in the extent to which these semi-endogenous factors have been aligned with the objectives of local capability-building.

National government policies

The central governments in Norway and the UK differed in their management of North Sea oil and gas development in three key ways: in managing the speed of depletion; in the emphasis on domestic capacity building; and in localization decisions. The main objective of this section is to summarize the main differences and their underlying causes. We pay particular attention to the different approaches in research and technology development.

In the early years of North Sea development in the UK, the problematic state of the British economy, with its massive balance of payments deficits and high unemployment, pushed the government towards a rapid depletion strategy. For Norway, on the other hand, there were no major macroeconomic imbalances in the 60's and 70's and unemployment rates were very low, ranging between 1 and 2%. 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 and in the worst case could collapse. Thus, the government could not afford to take a fast depletion route, and the principle of gradual development coupled with Norwegianization permeated its policies through the mid 90s.

The policies of the Norwegian government were consistently focused on domestic capacity building from early on. This was reflected in the establishment of a national oil company, Statoil; in specifying licensing conditions; and in promoting technology transfer from foreign companies to domestic organizations. It was clear to everyone that the government was systematically rewarding operators who were contributing to domestic capacity building.

Until the late 90s, the Norwegian government decided which operators should work in each field. One oil company was always given the role as the main operator in charge of field development. Arrangements for multiple operator ownership encouraged collaboration (and sometimes conflicts) on strategies, development solutions and technology.

Central government decisions enforcing agglomeration led to the location of both Statoil and the Norwegian Petroleum Directorate (NPD) in Stavanger. In contrast, the UK's locational decisions did not contribute to agglomeration. Glasgow was selected as the location for both the British National Oil Corporation (BNOC) and the Offshore Supplies Office (OSO), even though Aberdeen was already attracting, to a considerable extent, oil related industry. These decisions reflected a high level of concern about the depressed state of the economy in the central belt of Scotland.

5.1.1. Research and Technology Policies in Norway

In 1979 the Norwegian government took a critical step towards domestic research capacity-building through the establishment of 'goodwill agreements'. Under this policy, the international oil companies were informed that they would acquire 'goodwill points' by contracting oil and gas related research and development to Norwegian research institutions. This would enable them to be regarded as serious contenders for obtaining concessions on offshore oil and gas exploration and production on the Norwegian continental shelf. The policy was implemented through a well-articulated system of evaluating operator contributions to domestic capacity building. Financial support for R&D was rewarded, and transfer of know-how along with financial support was rated even more highly. The international companies' overall contributions were rated and reflected in terms of their standing in the next licensing round. The goodwill agreements gave the institutional research sector a significant boost. These agreements were part of a larger set of 'agreements' called the technology agreements. It was a policy line that forced national and international oil companies to develop Norway's oil and gas related knowledge base. It ended in the mid 90s due to the conflict with EU regulations.

For operators on the NCS, the tax system has promoted R&D spending by classifying R&D-related costs as immediately deductible. The tax rate of 78% generally implies that the state covers 78% of the costs. Many R&D projects are included in license-related financial accounts, in which the licensees share costs.

The central government also took a direct funding role for industry-relevant research. Throughout the 80s and 90s public funding remained significant for industrial R&D as a whole. It was not until the mid 1990s that privately funded R&D came to account for more than 50% of overall R&D expenditures. Figure 5.1 illustrates the structural shift in Norwegian r&d spending.

R&D funding by oil and gas companies grew rapidly through the mid 1980s and came to account for a significant fraction of industrially oriented R&D. During the late 1980s, oil and gas companies alone funded around 12% of Norway's total R&D expenditures (public and private). During the 1990s the oil companies have funded around 7% of total R&D expenditures in Norway on average (public and private). The decline from 12% to 7% can be attributed to the termination of the goodwill agreements.

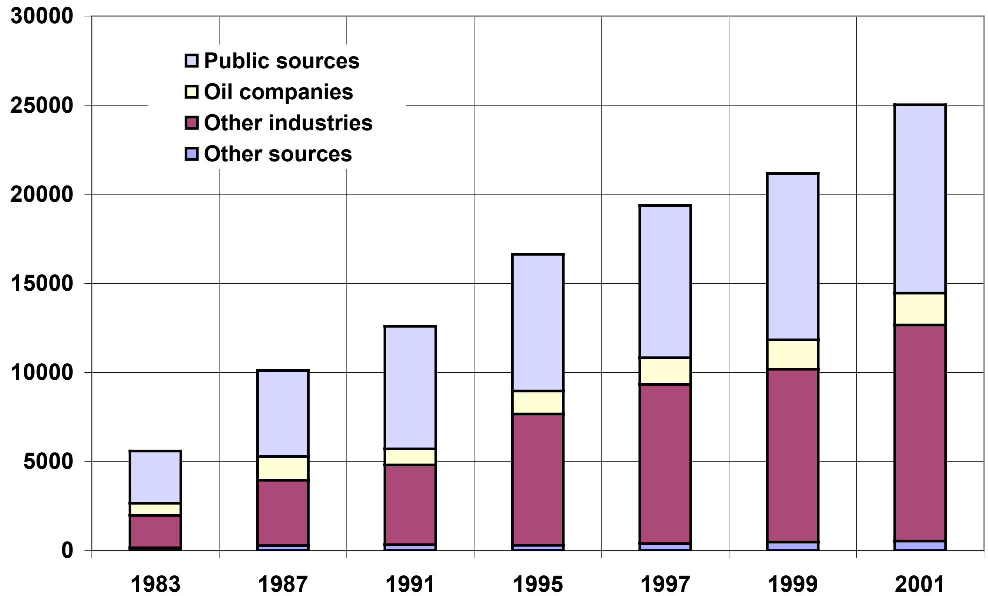


Figure 5-1: R&D funding by sources private/public 1983-2001 (mill. NOK, nominal)

The publicly funded research programs in the oil and gas sector introduced in the last decade have taken on a significant role. The five major programs are Ruth, Force, Offshore 2010, Demo 2000 and Petromaks

The *Ruth* research program (Reservoir Utilization through advanced Technological Help) was initiated in 1991 as a co-operation involving the Norwegian Research Council, the NPD and several oil companies and public research institutes. The program produced significant results in a short time period, attracting industry attention and new business participants (Karlsen et al. 2000). The two most important technologies to come out of the Ruth effort were gas injection and combined water and gas (WAG) technologies, whereby water and gas are pumped alternately into the reservoir to improve recovery rates. When the program came to an end in 1996, 18 oil companies had participated. In the course of the Ruth program period, the average planned recovery rate for oil from existing oil fields increased from 34% to 41%. This corresponds to two average size North Sea oil fields. Compared to the moderate R&D investment of MNOK 105 this amounts to an exceptional return on R&D.

From the late 1990s, the applied R&D program *Offshore 2010* has been the main R&D endeavour of the local suppliers and oil services industries. With limited funding, the bulk of the R&D is carried out in the offshore supplier and services industry (65% of total expenditures) and in the education and research sector (35% of total program expenditures). The main funding has come from the Norwegian Research Council (NRC)

(30%) and the upstream oil and gas industry, including oil companies (70%). By the end of 2001 a total of 316 million NOK had been allocated to the program. The main R&D institutions involved have been the Norwegian University of Science and Technology (NTNU), the Institute for Energy Technology (IFE), the Foundation for Scientific and Industrial Research (SINTEF), RF–Rogaland Research and Christian Michelsen Research. Some 60 offshore companies had participated in Offshore 2010 R&D projects by the end of 2001. The main technology areas covered are subsea production, drilling technologies and well/fluid transportation technologies. SMEs figure prominently as project participants.

The *Demo 2000* program was initiated in 1999 with the aim of developing new oil and gas fields on the NCS through new technology, improved security of execution within budget and planning and new industry products for the global market. In addition to public funding that currently stands at a total of some 250 million NOK in nominal value, the program has assured funding from private sector companies and R&D institutions of twice this amount. Current Demo 2000 partners include the Ministry of Oil and Energy, four public R&D institutes, six oil companies and a handful of specialised oil and gas suppliers.

The many government petroleum research programs co-funded with oil companies and firms in the offshore services and supply industry of the last 15 years illustrate the collaborative efforts in the Norwegian innovation system in upstream oil and gas.

In addition, the Norwegian Research Council initiated a new oil and gas innovation program (OG_{21}) in 2002. The aim of the program is to develop a national technology strategy. This strategy represents a consensus-based approach to the industry's views of the most important and urgent issues to be addressed by research and technology development. The national technology strategy will be implemented in and by the industry, taking advantage of existing operational options such as the relevant programmes of the Research Council of Norway (Petromaks, PetroForsk, Oil and Gas), Demo 2000 and other industry initiatives (Cord, Force, Deep Community).

Since autumn 2002, OG_{21} has appointed seven oil companies, all operators on the NCS, as Lead Parties (LP) to conduct a detailed evaluation of the Technology Target Areas (TTA) which has been identified during the strategy process.

The technology goals defined in OG_{21} are the starting point for Petromaks, a program established to improve recovery from producing fields and increase access to new reserves. The key research areas are

- Exploration: development of geophysical measurement methods, exploration and reservoir models and improved understanding of basin formation
- Increased recovery in a wider perspective: methods for stimulated recovery, reservoir monitoring and control, drilling technology, as well as new processes, methods and technology for gas supply.

In addition to more applied research programs like OG_{21} and Petromaks, there are also ongoing initiatives intended to strengthen basic research. Along with numerous SIPs and SUPs (multi-year strategic research programs aimed at R&D institutes and higher education institutions), Petroforsk is an example of a basic research program. These initiatives are intended to address long-term research requirements and issues related to the oil and gas industry. The main deliverables for these research initiatives are measured in terms of PhDs and post-graduate candidates.

5.1.2. Research and Technology Policy in the UK

The basic understanding of the UK government was that it was up to industry to undertake its own R&D. Government support for R&D was therefore focused on licensing and regulatory-related issues such as reservoir engineering and safety as well as basic research.

In the 1970s there were two principal, albeit small, channels through which government supported research. In 1973 the Department of Trade and Industry (DTI) brought together all the pieces of relevant R&D, which were subsequently transferred to the Offshore Energy Technology Board (OETB), established under the Department of Energy in 1975. The main emphasis of OETB was geological work to support licensing policy, as well as safety and other technical issues to support government regulations (Cook et al 1983). Its overall budget grew modestly from 10 million pounds in 1976 to 20 million in 1981, though industrial support was quite small - of the order of 3 million pounds a year or about a sixth of the total spending. Cook et al. conclude that government support of industrial R&D has been 'piecemeal and miniscule'. It was also small in comparison with available support from EU, whose hydrocarbon program was running with a budget of about 20 million pounds a year, a third of which was won by British applicants.

Two types of technical capacity were developed under OETB: the Marine Technology Support Unit (MATSU) within the Atomic Energy Agency (AEA) in Harwell, to oversee safety and technical integrity issues, and the reservoir engineering group within AEA at Winfred. AEA, the government research and development agency for nuclear technology, already had strong ties with DOE (and its Chief Scientist at the time was a nuclear scientist). A later employee of MATSU remembered: "We used to see people working for MATSU as redundant nuclear engineers – being recycled for oil." A professor at Heriot-Watt recalls that their director of petroleum engineering was surprised that such initiatives did not come to them. The oversight for MATSU was later moved from DOE to the Health and Safety Executive (HSE).

Both of these units shrank over the years, particularly after privatization of AEA in 1996. One AEA staff member recalled that that although AEA did its best to work in oil and gas, it was not easy, because,

> "It is a nuclear company with a civil service background trying to work with oil and gas, which is very private British/American – so there was a cultural problem.

> Nobody at the senior level in AEA understood oil and gas – the chairman of AEA could not talk to the chairman of BP about oil and gas."

The second avenue was the Science and Engineering Research Council (SERC), whose funding was increased from 1977 as it developed a new disciplinary area, which led to the establishment of the Marine Technology Directorate (MTD). Although the total size was small, this was a significant development for universities that conducted research in such fields (Cook et al). Later, in the early 1990s, the MTD developed a company in Aberdeen through which support for industrial R&D of the order of 5-6 million pounds a year was provided.

In 1983, a new licensing requirement designed to involve UK firms in R&D contracts was introduced and OSO became responsible for monitoring. The idea was to give preferential status in licensing to operators investing in domestic R&D. This came five years after the Norwegians' goodwill agreement policy. But that short time lag was perhaps critical, particularly given that large fields were no longer the norm in the UK and there was less at stake for operators in gaining favorable licensing status.

Local government policies

The regional authorities played not only a key role in bringing foreign investors to Stavanger but also contributed to continuous development of infrastructure, including human capital, by establishing both the University of Stavanger (UiS, formerly known as Stavanger Regional College) and RF-Rogaland Research and the adjacent Research Park. This latter role is lacking in Aberdeen. Both the University of Aberdeen and Robert Gordon University (RGU) had a long history, and it was more difficult to influence long-established institutions. Indeed, RGU was independent of the local government in Aberdeen even before 1992, when the norm was for British polytechnics to be owned by local governments.

However, more critical was the different expectation about the role of regional authorities with respect to universities. A former Scottish Enterprise executive recalls how the Scottish Executive recruited a consulting company to conduct regional competitiveness analysis along the lines of Michael Porter's cluster model. One of the key recommendations made by the study was to strengthen university-industry relationships, a route not followed. The main reason was that Scottish Enterprise, the key development agency, was legally not allowed to fund universities – and this restriction lasted until several years ago. Building education or research capacity was perhaps not an obvious objective for local and regional authorities at the time.

Another factor that may have influenced local and regional authorities' ability to take steps is constant organizational changes. Aberdeenshire had been behind the set of infrastructure initiatives in the early 1970s, and it was these actions that helped attract foreign companies to Aberdeen. In 1975, a two-tier local government system was introduced, and development responsibilities for Aberdeenshire were split into the

Grampian Regional Council which was to become responsible for most social and infrastructure services, and the Aberdeen District Council which was to be responsible for housing and local planning. The North East Scotland Development Agency (NESDA) became one part of the Regional Council.

Organizational changes have not ended there. The Scottish Development Agency was founded in the early 1980s for the economic development of Scotland, funded directly by the UK government. Then a decision was taken in the early 1990s to make it have a wider remit and it was merged with the Scottish part of the training agency, and became Scottish Enterprise. At the time of Scottish devolution in 1996, local governments were restructured again to reduce the number of layers. Aberdeen City Council and Aberdeenshire Council were established as neighboring councils. Economic development responsibilities were taken away from the City and given to Scottish Enterprise, though the City has recently revived such a function. Neither the city nor Aberdeenshire have sufficient resources to take economic development seriously.

Interviews with local authority officials indicated that there was a clear sense of the role of local authorities until the mid 1980s: this was to entice companies to come to Aberdeen. It was only in the mid 1980s that the emphasis changed to innovation. The Offshore Technology Park and the Science and Technology Park were developed by Scottish Enterprise starting in the late 1980s to support the high tech component of the oil industry. BHR (later Caltec), which at that time had the world's biggest multiphase flow loop, was invited by Scottish Enterprise to move a significant part of its research facilities to one of the technology parks in Aberdeen and did so in the mid 1990s. The Scottish Development Agency in collaboration with Grampian Regional Council initiated the Scottish Subsea Group in 1991 to address the perceived problem of users of technology not picking up on the many good technological ideas that existed. However, the operation was based on very limited public support of 250,000 pounds a year, and recently became subsumed under a similar initiative for the UK as a whole, Subsea UK. One expert involved in the Scottish Subsea Group regrets that this is happening 25 years too late – and that if such actions had been taken earlier, British subsea technology would have been far more competitive today.

There is a common understanding that Aberdeen had a real competitive edge in subsea technologies until the 1980s, but that this was gradually lost over time, most notably to Norway and Houston. Local and regional governments did very little to keep such local capabilities, in spite of efforts to think long-term, as exemplified by a commission headed by Sir Ian Wood in 1984-88 on 'Aberdeen beyond 2000.' In the words of a former Scottish Enterprise Official, "investments dried up and the centre of gravity moved to the Gulf of Mexico."

One official from Aberdeenshire Council reflected that they could learn from Houston, which had a strategic technological approach in building on strengths, in focusing on key technological areas such as subsea technology, but also in diversifying into new areas such as medicine. He thinks that Houston's strategies were based on a conscious decision made at a high level, which helped attract specific expertise into universities to build centers of excellence. The interesting aspect of such a commentary is not so much whether Houston actually did this or not, but the fact that Aberdeen people are thinking about such actions as missed opportunities.

More recently the city government's focus shifted to export promotion – for example, organizing promotion visits to key and emerging oil producing regions. There are some other assistance programs by the Chamber of Commerce, but none go beyond simple orchestration of business visits.

Some Aberdeen industrialists complain about the inadequate infrastructure in Aberdeen. Industrial estates are scattered in all directions from the city centre, often linked by small bridges, whose capacity limits the traffic. In comparison, in Stavanger there is a logic of agglomeration reflected even at the micro-level, with research institutions, for example, concentrated in one area.

One energy journalist based in Aberdeen criticized the lack of policy focus on either export promotion or diversification. On the need for export orientation, he recalled that Sir Ian Wood (CEO of the Wood Group, and a well respected businessman in Aberdeen) has been pushing for the need to focus on exports since the 1980s, and yet little has been done. He further observed that there was no organization focusing on the issue. Again, we witness a stronger coordination effort in Stavanger with the establishment of INTSOK, a joint public and industrial organization to promote exports.

On diversification, there are two recent developments which show the new commitment of local and regional governments to building research and technology capabilities. First, there is an emerging focus on renewable energy orchestrated by a local working group comprising representatives from local governments, industry as well as universities. The group has been coming together to discuss issues since 2000. A tri-partite dialogue is finally taking place.

Second, Scotland announced a 450 million pound initiative to establish three flagship technology institutes in areas of strategic importance: energy, life sciences, and techmedia. The Intermediary Technology Institute, Energy (ITIE) has been established in Aberdeen and has started funding/commissioning research projects with significant commercialization potential. The idea is to build on capabilities in oil and gas in Aberdeen, and address broader energy issues of the future, though ITIE is expected to operate globally, not just in Aberdeen or Scotland.

Financial institutions

[32] Number of publications in SPE's eLibrary, which includes papers presented at SPE conferences (since the late 1950s) and in SPE's technical journals (since the early 1950s).

The availability of private finance is a key requirement for innovation, and our interviews revealed significant differences between the two regions in this regard. One difference has to do with the sponsoring roles of operators. The involvement of operators is critical to the introduction of technological innovations to the oil and gas industry, and their implicit and sometimes explicit funding has often served to bridge the financing gap for innovating companies. In Aberdeen, BP and Shell have traditionally fostered innovations this way, but their involvement has diminished since the 1980s and even before then may never have been as great as that of Statoil, whose institutional mandate from the outset was to support local innovations and capabilities. At its Stavanger headquarters Statoil employs approximately 100 persons in finance-related activities (including an in-house insurance company and capital management functions.) The company can thus draw on significant local knowledge related to mergers and acquisitions, as well as credit and risk evaluations.

The international oil companies and the integrated service companies have only limited financial functions in Stavanger, and rely on Stavanger-based banks for payments systems and transfers. The many regional service providers and niche companies are financed by regional banks. Their size and capital intensity are generally compatible with the capabilities of the regional banks. So-called non-fulfillment agreements are a common feature of bank financing packages, especially when related to innovations and product development. These contracts imply that companies need to fulfill certain predetermined requirements related to profitability and equity. The banks rarely take active roles in financing the earliest and most risky stages of the innovation process. However, they are involved indirectly through investment and venture capital companies. As part of their financial advisory role, the banks mediate between their customers and potential investors, commercialization companies and the public support system. The regional banks compete on the basis of their geographical and social proximity to the oil related service and supply sector, access to relevant knowledge, flexibility and quick decision making.

In the UK there is evidence that the large City banks were rather cautious with respect to the financial needs of the UK oil and gas industry in the early days (Cook et al 1983 and interviews). There was the usual conservatism about a new industry, with skepticism and uncertainty as to how significant and durable it would be. The industry's image was also tarnished by the spectacular 1975 failure of Burmah Oil, a well established British oil company. One interviewee thought that the City banks remain largely uninterested in the oil and gas industry even today.

Several interviewees pointed out that the lack of venture capital has also been a factor that constrained the growth of innovative companies in Aberdeen. According to one,

> 'The poor availability of VC funding was a big deal particularly in Scotland. Recently, I checked up the numbers with a director in PWC, and found that of 262M available for early stage start up, when 30% was spent around London, only 7M went to Scotland. I was surprised that it was so low. This means that including all the private money such as angels, there would probably be 20M private money and only 40-50 M including the Scottish Enterprise money.

> Compare that against Norway, which has roughly the same population as Scotland – when I was in Norway, I was asking around, and I was told 120M with 25 VCs and banks! In Scotland, there is no Scotland-only VCs….'

This view is consistent with a venture capitalist's observation that he found Norwegian companies to be more 'mature' when they come for venture capital funding than their Aberdeen counterparts. The same venture capitalist lamented that there has only been one generation of UK entrepreneurs – many of them in Aberdeen – in the late 80s to 90s and that there is no generation to follow. It is this group that includes well-known success stories like Charlie Anderson of Andergauge and Larry Kinch of PES.

The puzzle of why there should have been only one entrepreneurial generation might be explained by the possibility that that generation grew up under a very different system of patronage. The oil and gas industry is fairly conservative, but there has been an internal financing mechanism in the form of some large oil operators who were willing to initiate, fund and support the development of new technologies, providing both technical and financial inputs to work with contractors (Cook et al 1983, interviews). As noted previously, BP and Shell were key players in this respect until the late 1980s. These firms in effect served as financial 'angels' to those developing new technological opportunities. Our interviewees reported that this avenue for financing new projects dried up in the 1990s, owing to three factors:

- considerable belt-tightening (particularly in BP)
- industry-wide consolidation of contracts to larger companies – which squeezed out small companies from innovative partnerships with oil majors
- internal reorganization within oil companies leading to field-based organizations and no 'technology champions'

In recent years, two energy related venture companies have emerged in Stavanger. One of them is co-funded by the state and by successful regional energy-related companies. These venture companies have had a number of successes, including the IPO of a greenfield oil company.

Concluding remarks

One interviewee remarked,

> *"What has impressed me in Stavanger is the esteem the industry has in the region and that goes all the way to the government. It seems to be a great deal of pride in what the industry has done. It is not there to the same degree in Britain, or even in Scotland. In addition, it seems to be more thinking about what to be done for the future in Norway, the planning seems to be much more developed."*

While the local government made concerted efforts to invite the oil and gas industry to Aberdeen, it is not clear that the local community welcomed the arrival of the industry wholeheartedly. Americans came to Aberdeen in large numbers and created an almost separate economy complete with American supermarkets, which imported everything from food to cat litter. For the locals, there was tremendous concern about the effect of the industry in raising costs – particularly for housing and labor. After 1986, when oil prices fell precipitously, many Americans left Aberdeen, leaving greater control in British hands. However, the subsequent stagnation of oil businesses did not help, as it reinforced the picture that many had – especially among the local population – that the industry was plagued by instability and job insecurity. Perhaps the 'us versus them' mentality, which had been present among the local community from the outset, never entirely dissipated. The fact that local institutions such as universities did not build strong ties to the industry (see Section 6) is perhaps a reflection of this broader view of the oil and gas sector as an ephemeral, unstable sector.

There have been notable differences in the role of the national governments in supporting the development of the oil and gas industry. The Norwegian government was consistently focused on local capacity building, including in research. Macro-economic conditions which supported a slow depletion policy were aligned with the objective of local capability development. In contrast, the oil and gas industry received only sporadic support – some have even described it as benign neglect – from the British government. Whitehall's policies on oil and gas fluctuated back and forth – in the midst of the massive industrial re-structuring that was taking place. The only consistent policy appears to have been rapid depletion – where the interests of the international operators found common ground with the need of the government to address the massive balance of payments problems of the day. The much smaller part played by the oil and gas industry in the UK economy as a whole may also have contributed to the generally lower level of UK government involvement. In the industry's formative years, the Norwegian electorate supported a strong state as guarantor of the principle that the oil and gas resources belonged to the people. In Norway, oil and gas revenues account for 1/3 of state income, compared to 1-2% in the UK. Oil and gas income is the key to the Norwegian welfare state and the health of the pension system, whereas in the UK, oil and gas contributions were no greater than a number of other industries, and did not command special attention.

6. Local innovation capabilities

If global industry dynamics and physical conditions are exogenous factors that influence the regional industrial development process, emerging local capabilities for innovation are the endogenous counterpart.

Measuring and comparing innovative capabilities is challenging. The capability to innovate includes the capacity to invent, as well as the marketing, distribution and implementation of new products, processes, systems, and services. Innovative capabilities thus relate not only to the capacity to invent, but the capability to put those inventions to use. In order to delineate these capabilities we have relied both on statistical data (numbers of patents and scientific publications) and information from the interviews.

In this section, we discuss the innovative capabilities of the two regions in general. We first consider the role of the industry itself and how it interacts with education and R&D institutions. We then focus on the institutions of higher education and research. In Section 7 we present an analysis of patenting behavior in the two regions.

Local innovation capabilities: Industry

6.1.1. Operators

In Norway, both Statoil and Norsk Hydro developed into leading operators as a result of deliberate 'Norwegianization' strategies, together with the considerable scope for technology development associated with elephant fields such as Statfjord, Gullfaks and Troll. Statoil was established in 1972 as a 100% state owned greenfield company. In the 1970s the Norwegian government also acquired majority ownership of Norsk Hydro, which was already one of Norway's largest industrial companies, in an attempt to secure Norwegian participation in the development of the industry. Today, these companies are two of Norway's largest in terms of both turnover and number of employees. They have played a critical role in sponsoring local innovations by working with supply and niche companies as well as large service companies. Over the past ten years, 50-65% of Statoil's purchases on average have been directed towards domestic suppliers.

Both Statoil and Hydro have also played significant roles in industrial innovation as demanding customers, project funders and providers of information and expertise. Statoil has stimulated innovation among integrated service companies through its practice of outsourcing research and technology development. Typically, it enters into long term framework agreements with the service companies based on openness and collaboration.

Norsk Hydro seems to prefer collaboration on case-to-case basis, since it has a strong R&D tradition as an industrial company. The operators pursue intellectual property rights in technological fields that they consider to be relevant to their core competence and where they compete directly with other operators, but in other fields they are more likely to relinquish IP to their suppliers. In such cases they gain competitive advantage as the first exploiter of the new technology, while paying licensing fees at a discounted rate.

Since 1991, Statoil has operated a program to develop and support innovative supply companies, which has provided opportunities for the development of local firms. Statoil or Norsk Hydro may play a critical role in the globalization of other Norwegian companies through social networks, in a similar manner as the French or Italians or even Americans are said to do.

ConocoPhillips is another operator which has had a special relationship with Stavanger. As the third largest energy company in Norway and with its pioneering and long-term role in its legacy field, Ekofisk, ConocoPhillips has long been a key player in the regional economy in Stavanger. Its constant focus on local content in supplies as well as its sponsorship of regional sports and cultural activities have helped to cement ConocoPhillips' key position in Stavanger.

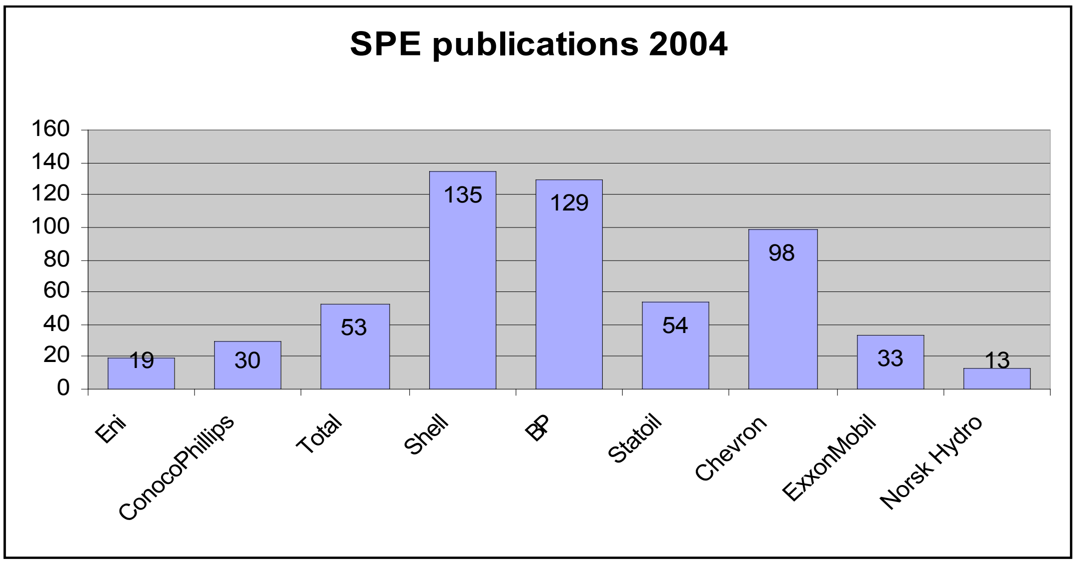
In contrast, operators do not appear to be consolidating their technological presence in Aberdeen. For BP, Aberdeen was more than just an operational centre for many years, in that many important technological developments originated there. The North Sea provided critical opportunities for BP to develop its technological capabilities in deepwater operations. This was particularly helpful for its entry into deepwater elsewhere (Acha and Finch, 2006).

BP's R&D groups used to be located in Houston, Sunbury, and Aberdeen. Many high-tech companies spun out or were started by former BP employees. However, BP has dramatically reduced its R&D activities in Aberdeen in the recent past and only 25 out of its total of 800 R&D related personnel are located there today. The locals complain that BP no longer plays the role of patron that it used to, in supporting innovations by local specialist companies. While BP's global HQ remains in London, its global businesses at this point seem no more likely to create advantage for UK firms, and more particularly to local suppliers in Aberdeen, than any other international operators.

There are indications that for BP, neither the UKCS nor Aberdeen is central to its operations – even though the company continues to be a significant presence in Aberdeen. BP was an important global company even before the North Sea resources were discovered, and today BP has exploration activities in 26 countries (compared with Statoil's 10). The company is aggressively pursuing a strategic focus on the development of large fields. This is illustrated by the sale of Fortes, its flagship field in the North Sea, in the late 1990s.

Many interviewees identified the major operators, especially BP, Shell and Statoil, as broadly active in R&D and innovation, and the dominant role played by these firms historically in the North Sea province is likely to have had an important influence on the formation and development of innovative capabilities in the two regions. One measure of innovative activity is the number of research publications by corporate employees. In Figure 6-1 we report one such indicator: contributions to publications by the Society of Petroleum Engineers (SPE).[32]

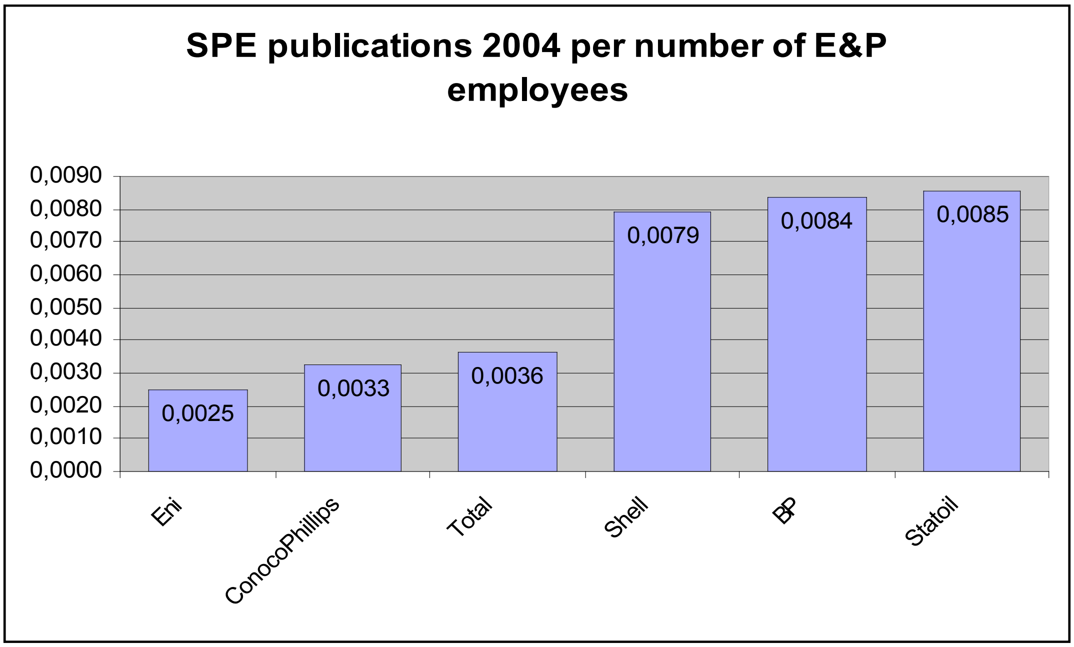
Figure 6-1: Number of SPE publications by operator, 2004



Source: SPE eLibrary database, accessed March 2006: http://www.spe.org

As shown in Figure 6-2 below, when adjusted for corporate size[34] Shell, BP and Statoil have similar SPE publication rates, and these are considerably above those of ENI, ConocoPhillips, and Total.

Figure 6-2: SPE publications adjusted for corporate size



Source: SPE eLibrary database and company websites

The data in Figure 6.2 are consistent with our interviews, which also pointed to the key roles played by Shell, BP and Statoil in sponsoring and using new technologies in both locations. Shell is known as one of the most technologically-driven oil companies. It contributed to the establishment of key facilities in both Stavanger and Aberdeen, such as the drilling testing centers in the two locations. It has also been a key sponsor of university research (for example at Heriot Watt) and has helped to develop key technologies by supporting work at innovative companies (e.g. Petroline). However, it is now consolidating its research base in Holland, and shows few signs of an active presence in Aberdeen. In Stavanger, by contrast, ConocoPhillips has recently invested in a major research collaboration project with a research institute – Rogaland Research (RF), and Shell, ENI and Statoil also have ongoing relationships with RF.

An important difference between the two regions is in the number of non-major operators – mid-caps and independents. Aberdeen hosts more of them than Stavanger. In the UK

[34] Number of E&P employees as of 31 December 2004 (we were not able to find data on the number of E&P employees at Norsk Hydro, Chevron, and ExxonMobil.)

these companies are considered to hold the key to the future health of the industry. This is because large operators are traditionally not able to deal with the small scale innovations needed to maximize the yield from mature fields. The normal expectation is that there will be a transition from international majors to independents as the fields mature. In this regard, Aberdeen is already seeing the arrival of innovative independents such as Apache and Talisman. In Norway this concern is less evident as large fields are still being developed. Here we expect to see a more differentiated role between the established majors and the new entrants.

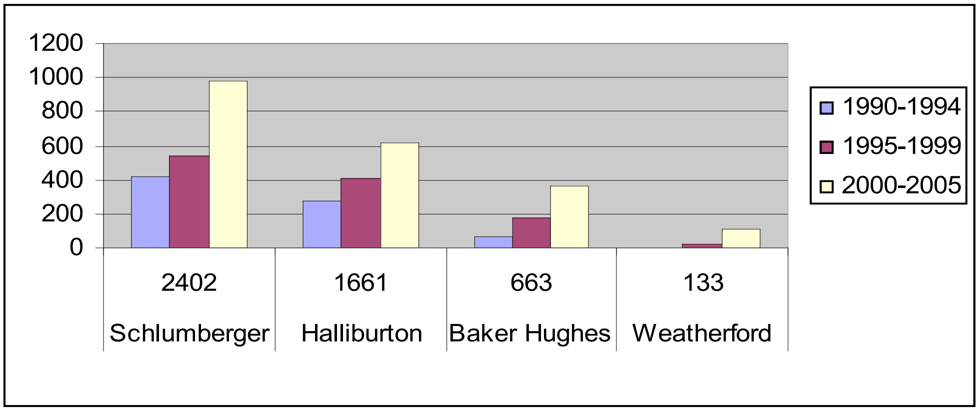
While most small operators in Aberdeen are not known to be R&D intensive, they clearly bring in different business models and are able to extract more from the existing fields through innovative approaches. Fortes, the flagship field on the UKCS, is more productive under Apache than it was under BP. Under BP in 2003, Fortes was producing 45,000 barrels per day. By the end of 2004, Apache had boosted production to 61,700 barrels per day. Independent operators are also contributing to the development of new kinds of local capability as they implement different business models regarding risk sharing and supply relationships. For instance, many smaller operators are willing to contract out key front-end activities which traditionally had been carried out by large operators. Similarly, BP's share in Gyda on the NCS was taken over by Talisman. The new owners have plans to double daily production. The new operators may stimulate the innovative capabilities of the service industry, as they often outsource activities that the majors carry out in house.

This difference is at least partly a reflection of the difference in maturity – Norway has perhaps a few more years before such a transition occurs. In contrast to BP, Statoil is committed to continuing its operations on the NCS, although these operations will gradually diminish as a share of its total activities worldwide.

6.1.2. Integrated service companies

The integrated service companies compete with each other for new technology, and secure it partly through their own innovations and partly by acquisitions of smaller, innovative firms. There are significant differences in strategy and approach among these firms. We did not carry out a systematic study of this question. However, one indication of these differences is shown in Figure 6-3, which reports the SPE publication rates of the four companies. Publication rates are on the rise in all four companies. However, Schlumberger is comfortably in the lead by this measure, with Weatherford trailing far behind. The ordering in Figure 6-3 is generally consistent with the comments from our interviewees regarding the technological intensity of the integrated service companies.

Figure 6-3: Number of SPE publications by the integrated service companies (cumulative totals also shown)



Source: SPE eLibrary database, accessed summer 2005: http://www.spe.org

While both localities have attracted all four integrated service providers, they appear to have done so in somewhat different ways. Stavanger has become the North Sea HQ of Schlumberger, the most technologically driven of the four, and Schlumberger has established a significant research capability in seismic and reservoir monitoring. Aberdeen, on the other hand, has attracted Weatherford, 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.

6.1.3. Service/supplier industry

In a study of supplier companies in the Norwegian oil industry, 58% identified themselves as niche producers (Steineke 1998). According to the 2003 Community Innovation Survey, approximately 55% of the suppliers in this industry are so-called innovative enterprises, meaning that they develop at least one new product, service or process per year.

In the Aberdeen survey of SMEs carried out in 2000, 77% of 192 companies surveyed were found to be ‘innovative’ in the sense of having developed new products or services in the last 5 years. 18% of SMEs were highly innovative and knowledge-based, while another 22% were innovative in new product development, albeit less cutting-edge or knowledge-based (Cumbers et al 2003). An earlier survey of 119 oil related companies conducted in 1996 found that less than a third of companies were undertaking innovations locally, with much of the leading edge research and development activity taking place outside the area, particularly in the South East of England (Cumbers 2000).

SNF (Kristiansen et al, 2004) reports that 45% of the supplier companies in Norway spent more than 2% of their sales in R&D in 2003, and 15% of them spent more than 8%. One in six companies had no R&D in 2003, compared to one in three in 2001. Two thirds of the companies say that collaboration in developing new technology is very important, a marked increase since 2001.

The table below shows the most important technology partners of Norwegian supplier companies, according to the survey by Kristiansen et al:

Table 6-1: Partners in technology development in Stavanger

Partner	Percentage of all SMEs[35]
Norwegian oil companies	55
Foreign oil companies	37
Norwegian industrial corporations	33
Norwegian engineering companies	23
Norwegian research institutions	19
Foreign industrial corporations	17
Foreign engineering companies	11
Foreign research institutions	7
n=179	

Source: Kristiansen et al. 2004

The Norwegian oil companies are the most important partners, which was also suggested by our interviewees. Foreign oil companies are the second most important collaborator, underling the vertical innovation processes in the industry. The table also shows that Norwegian companies and institutions are generally preferred as partners compared with foreign actors, indicating the importance of geographic and cultural proximity. Finally, research institutions play a minor role.

In Aberdeen, a little under a third of surveyed companies (n=192) reported collaborating with oil operators (see Table 6-2, Cumbers et al, 2003). A third also reported collaborating with major contractors. About 15% had collaborated with universities or research institutes, with more than half of these links being local. However, the depth of collaboration is limited both in terms of the number of collaborators and the frequency of collaboration. In a follow-up telephone survey, only 23% (or 8 firms out of 34) reported regular collaboration with non-customers. Also, while 80% of firms reported local

[35] On a scale from 0 to 4 the respondent were asked to rate the importance. The percentage include those that marked 3 or 4 (n=179). (Kristiansen et al. 2004)

support for innovation, 55% reported the importance of non-Aberdeen sources of support, showing the extent to which firms are networked outside of the region.

Table 6-2: Collaboration in Aberdeen

Collaborator	Firms (n=192)	%
Oil companies	58	30%
Major contractors	61	32%
Other SMEs	37	19%
Universities and research institutes	28	15%
Other	11	6%

Source: Cumbers et al 2003

The data in Tables 6-2 and 6-3 are not directly comparable, since they result from two quite separate surveys conducted under different conditions. But some of the data are broadly suggestive of findings from our interviews and other sources. For example, interactions with operators appear to be significantly more common for the SMEs in Stavanger, where 55% of the surveyed firms reported such collaborations, compared with just 30% of Aberdeen SMEs. Also, a somewhat higher percentage of the Stavanger SMEs report collaborations with research institutions (presumably including universities) than their Aberdeen counterparts, although the differences here may be too small to be significant.

One difference between the two regions is in the composition of this sector. As discussed in Section 2, Aberdeen has nearly twice as many smaller supply companies as Stavanger. This could have important implications for the innovative capabilities of the two regions, but further comparative research will be needed in order to assess this question.

Local innovative capabilities: Higher education and research

A striking difference between Stavanger and Aberdeen is in the role of local universities and research institutions in the two regions. Stavanger has developed a university and a public research institute, both with significant oil and gas related technical capabilities, while the two universities in Aberdeen have been much less proactive in developing technical capabilities relevant to the industry.

In some ways it is not surprising that the two institutions in Stavanger should have developed closer industry ties than those in Aberdeen. Both the university in Stavanger (UiS) and Rogaland Research (RF), a public research institute, were established more or less coincident with the founding of the oil industry in the region, and their subsequent development was directly shaped by the industry. Established in 1969 as a regional college, UiS always saw its role as serving the educational needs of local industry. Working closely with the oil and gas industry to provide key educational programs was thus a natural part of its mission. The college was the first to introduce an undergraduate program in petroleum engineering, and today produces the largest number of petroleum related graduates at the masters level in the country.

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.

In contrast, Aberdeen's two universities – Robert Gordon and the University of Aberdeen – were both very well established institutions when the oil was first discovered, [36] and they were not as responsive to the technological needs of the nascent industry. Aberdeen University, a 500-year old academic institution, is often said to have "missed the boat" with respect to the oil and gas industry, even though individual academics from a variety of disciplines have developed less visible but deep relationships with it. Robert Gordon, 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 University, which is located in Edinburgh, about two hours by train from Aberdeen, developed a national and later international reputation for petroleum engineering. One interviewee suggested that Heriot-Watt's early and decisive entry into the key field of petroleum engineering actually made it more difficult for the Aberdeen institutions to enter the field subsequently.

The story of these institutions cannot be told without reference to their national peers. In Norway, older, more established universities such as Bergen and Oslo had a strong focus on basic sciences, while Trondheim (NTNU), which was a technical university, developed a stronger focus on applications along with its affiliated research institute, SINTEF. The UiS/RF pair is considered even more applications-oriented than NTNU/SINTEF, which also covers a broader range of fields. Such differentiation is at least partly by design; UiS's strategy was to be different from other established institutions.

In the UK, Imperial College, London is the best-known university with expertise in petroleum engineering, and had the only significant petroleum-related educational programs in the country at the time of the discovery of the North Sea oil. Most interviewees appeared to place Imperial College in the same league as Heriot Watt as far as petroleum engineering is concerned, even though Imperial College is ranked among the best four universities in the UK, while Heriot Watt would be considered an upper middle tier institution. However, other universities, such as Strathclyde, Southampton, and

[36] Although Robert Gordon was a polytechnic, a vocational training college, rather than a university before 1992.

Cranfield, were also often mentioned and appear to enjoy greater technological recognition than either of the universities in Aberdeen for their contribution to the oil and gas industry.

There have been no public research institutes in Aberdeen in oil and gas-related areas, However, Caltec and AEA – two former government research groups that were subsequently privatized – both have a presence in Aberdeen. Caltec moved some of its research facilities to Aberdeen in the mid-1990s, with support from Scottish Enterprise. AEA's most important research laboratories remained elsewhere in the UK. Frontline Management (2000:56) argued in its report to Scottish Enterprise that "there is a widespread complaint that the R&D infrastructure is inadequate to support the development of the petroleum industry. This is largely being left to the companies which are, however, too small to bear the cost."

6.2.1. Role of government

Another significant difference between Stavanger and Aberdeen is in the role of the government in the development of local education and research institutions.

The Norwegian government was critical in initiating UiS's contribution to the industry. In 1970 the government quickly set up an expert committee for education in oil technology at Stavanger College, and two months later decided to start a three year program in oil technology. RF was created by the regional authorities in order to conduct research on the social impacts of the emerging industry.

Subsequently, the government played a critical role in the development of these institutions by requiring operators to conduct/sponsor research. In the 1970s, College/RF's early petroleum related activities were often prompted by the government. For instance, the Norwegian Petroleum Directorate forced Phillips to analyze core samples of crude oil from each well at Ekofisk, and Phillips did not have the internal capacity at the time to conduct these analyses itself. This was the reason why the company established contact with the college and RF. A loan (NOK 1 mill) was provided to the college/RF to build a laboratory. The loan was paid back through carrying out lab-work. For each analysis performed in the lab on behalf of Phillips, a certain amount of the loan was repaid. This laboratory was for years RF's cash cow. The knowledge developed from Phillips' studies was presented at international conferences. Generalized knowledge was thus acquired through user-oriented and problem solving research. RF has continued its close relations with Phillips through the years.

At RF, the petroleum department grew to fifty employees in seven years. The growth was stimulated by a decision of great impact taken by the Storting (the Norwegian Parliament) in the fall of 1979: the oil companies were required to do research in Norway in order to obtain future exploration and exploitation concessions on the NCS. These official requirements became formalized through framework agreements, which came to be known as "technology agreements". Projects within these frameworks were supposed to transfer knowledge and technology to Norwegian industry and research institutions. RF proposed to the Government an extensive project on multiphase flow, but lost out to Trondheim. A joint proposal from the University of Trondheim/SINTEF and Stavanger College/RF to develop centers of expertise in petroleum technology in the respective regions received Government approval in 1981. The research centers were financed by the foreign oil companies with an upper limit of NOK 230 mill. The plan implied steep growth at RF, from 53 petroleum related positions to 135. The primary objective was to stimulate applied research and support petroleum-related education. The agreement with the oil companies was signed in November 1982 (Johnsen, 1999). As a result of this, RF built Ullrigg, a full scale test facility for drilling, with "goodwill money" from Shell (150 mill nok) and Statoil (30 mill nok). The facility was completed in 1983 and since then has been one of the cornerstones of RF's portfolio of activities.

In Aberdeen, universities were autonomous and made their decisions independently of the government, and the government also largely bypassed these universities in their investment decisions about training facilities. This is not to say that the UK government did nothing to support universities; universities nationwide did receive funding support for research related to oil and gas. However, the most significant government research support was given to existing government laboratories and no effort was made to create new and specialized research institutes. This difference at least in part reflects differences in the attitudes of the two governments towards the oil and gas industry. Norway had a much more strategic and long-term view of the oil and gas industry than the UK, partly because of the larger size of the industry with respect to the rest of the economy.

The other difference is that when the North Sea oil industry began its operations, there had already been a long history of UK involvement in the international oil industry, and some universities already had petroleum-related expertise in place. Imperial College in London had significant educational and research capabilities in petroleum engineering, but these were considered inadequate. An interdepartmental government report in the early 1970s pointed out the need for a postgraduate education program in offshore engineering. The initial idea was to establish it in Aberdeen, but the university there was reluctant to get involved in an industry whose life was expected to be short. Heriot Watt managed to get into the game quickly and established its one-year masters program in Petroleum Engineering in the mid 1970s, with key support from the government.

However, this move in support of local universities appears exceptional rather than the norm. In 1975, the Petroleum Industry Training Board established a drilling technology training centre in Livingston unconnected to a university (BB 1976). In the same year, the underwater training centre was established at Fort William. In 1977, the drilling technology training centre was moved to Montrose (BB 1988), and the Petroleum Industry Training Board was reformed into the Offshore Petroleum Industry Training Board in 1982 (BB 1983). It was only in 1987 that Aberdeen Technical College was commissioned to have a ballast control simulator for training. Around the same time, a new drilling facility similar to Ullrigg was established in Aberdeen, but unrelated to any local university or college (BB 1989).

Enhanced oil recovery research and reservoir simulation research were both undertaken at AEA – in Winfrith and Harwell respectively – principally because AEA was the key research body associated with the Department of Energy. In 1989, another significant facility was constructed for the calibration of nuclear oil field logging tools in Aberdeen – but this was established inside AEA rather than affiliated to universities.

6.2.2. Institutional responses

Though the governments in both countries played key roles, the most significant differences were in the institutional responses of individual universities. UiS responded quickly and consistently to industrial needs. So did Heriot Watt. The University of Aberdeen, however, opted not to develop institutional ties to the industry until very recently, and RGU's early response was not translated into a sustained commitment to maintain and further build the capacity to work with the oil industry, even though it had been heavily networked with it.

An interesting aspect of the situation in Stavanger was the close alignment between UiS, the regional authorities, and industry, which exerted considerable pressure on the national government over a long period to realize the regional goal of establishing a true university in Stavanger. Petroleum- related research and education was a decisive factor in those efforts, which succeeded in 2005 when UiS became the fifth university in Norway. In effect, the oil and gas industry spearheaded the establishment of the university.

In June 1970, when Ekofisk was declared economically feasible, there was no oil-specific technical education in Norway. At the time, Stavanger was home to a regional college and a technical college. The two institutions set up a coordinating committee at the regional level. As noted earlier, this is when the government acted very quickly to come to a supportive decision to start a three-year education in oil technology in Stavanger. The manager of the program was American, and in addition to three permanent teaching positions, guest lecturers from the oil companies and from the French Petroleum Institute took responsibility for courses. The first class of petroleum engineers enrolled in 1971 and graduated in 1974. From 140 applicants, 30 students were admitted. In subsequent years admissions increased to 70. At the time of the graduation of the first 30 students, a large number of them were already employed in the industry, ten of them with Elf. After language courses in France and fifteen months' internal education in Elf, they were sent offshore to work as operators at the Frigg field.

The college was at that time the only one that offered a 3-year engineering program, and the only institution offering petroleum-focused education. Trondheim followed two years later. The three-year program covered drilling, reservoir technology and oil recovery. The diploma was a qualification for membership in the Society of Petroleum Engineers. A committee of American Education visiting the Nordic countries in the mid 70's found the program to be equivalent to an American Bachelor of Science degree. Hence, this regional program won legitimacy with the global oil companies, and the certification made it easy for Norwegian candidates to be accepted to American master programs (Johnsen, 1999)

People involved in the early days of petroleum education in Stavanger recall this period as rather chaotic. As Professor Skjæveland at UiS noted: *"We enrolled the first class without having personnel with knowledge on the field"*. However, the institute sent its lead physicist, Rasmus Risnes, to Paris to learn about petroleum issues. In addition, both students and faculty were sent offshore to learn. When they returned, they shared their newly acquired knowledge with the class. Students got the opportunity to combine theoretical studies with practical work offshore. Professors from foreign universities and industry people were also used extensively during the first years. The regional college took on a regional role from the outset. The vision of the college at the time was "to enter into the region". The regional enthusiasts had also registered that a mere 1% of Norway's public R&D spending was channelled to the region.

The strength of UiS's commitment to serve the emerging industrial needs can be seen better in their establishment of a civil engineering programme. In the mid-1970s, forecasts indicated a future shortage of civil engineers – particularly given massive requirements for platform construction. The University in Trondheim, the only institution offering civil engineering education at the time, hinted that it was unable to meet the demand. A partnership between the technical college and Stavanger College led in 1975 to the offer of "a one-year crash program in petroleum engineering" to graduated civil engineers and other engineers. Trondheim's lukewarm response triggered Stavanger College to send its plans to a Government committee in January 1977. The regional authorities and the business community were clear in arguing that a civil engineering education would have great regional impact: a regionally based education had a great potential for industry's direct contact with education and research. (Johnsen, 1998). The committee agreed to the additional need, but could not decide on its location. The Minister of Education was also sceptical about the financial support that the Norwegian oil companies were proposing to provide.

The Stavanger College decided to go ahead with the unofficial civil engineering programme without government support. This was an audacious move, very unusual for Norwegian higher education institutions, and it made quite a stir within the sector. But for UiS, the rationale was clear; the dialogue with the oil industry revealed emerging educational needs for the oil *production* phase – most notably related to platform construction. They had developed the plans for the programme, why not implement them? Since the regular road to civil engineering education was blocked, the program was defined and introduced as a post-qualifying education. The program was supported and financed by the industry itself. Ironically, the program was unofficially encouraged by the ministry. The introduction of the plans followed in the wake of the Bravo blow out, and the authorities were in need of showcases.

The first course was carried out with help from American professors, specialists from R&D departments in the oil companies in Europe and the US, and Norwegian institutions (Johnsen, 1999). In 1979 the Stavanger College decided to expand the program, this time marketed as “cand.techn” to avoid the University of Trondheim’s monopoly of the term “civil engineer”. 29 candidates completed this program. Finally, in 1985 the official education of civil engineers started in Stavanger. The knowledge transfer from abroad was by then complete as all teaching was carried out by personnel from the college. Eight professor positions had been established.

Strategically, the Stavanger College had no intention of copying universities or other technical colleges. It sought to differentiate itself from other players by combining basic scientific disciplines such as mathematics, geology, and chemistry with more applied technological disciplines like drilling and well completion. So the college/university managed to build an education programme that had a scientific and theoretical knowledge base with practical applications superimposed on this. In the period from 1971 to 1985, 500 engineering candidates earned bachelor’s degrees. The industry considered the graduates as knowledgeable and highly adaptable for their needs.

Today, UiS is also known for a wider range of education programs with relevance to the petroleum industry, including project management, risk management, human resource management, HES (health, environment and safety), business economics and petroleum economics. The prevailing thinking has been: if we can achieve leading edge status within petroleum education and research, other disciplines will follow suit. UiS has also developed a range of petroleum-related research activities. Some are done solely in-house and some are done in collaboration with research institutions and/or industry. These activities are financed by the Norwegian government, industry or a combination of the two.

On the UK side, Heriot Watt and the two universities in Aberdeen provide contrasting images of institutional commitment. Heriot Watt did everything to establish petroleum engineering as a new interdisciplinary center; the University of Aberdeen did everything to obstruct it; and RGU responded – but only as a short-term measure.

Heriot Watt was probably one of the earliest in the UK to establish a dedicated office to handle industrial relationships in the 1970s. When the university was contacted by a large oil service company to look at the issue of water discharge in the early 1970s, the university was able to send an interdisciplinary group of academics (one mechanical engineer, another from civil engineering and the third from marine biology) to undertake the consultancy task. Soon, Tom Patten, the then head of mechanical engineering, came up with the idea of creating a new interdisciplinary center for petroleum engineering. The idea was institutionally supported, an advisory board with industrialists was set up, and the university started its systematic effort to attract funding and other support from the government and industry alike. Tom Patten worked hard to get funding support not only from the University Grants Committee (the funding body for universities at the time), but also the Department of Energy and industry for the establishment of the program. Shell agreed to provide the university with the first head of the program, and this individual brought to the university much-needed expertise for training from Shell.

The University of Aberdeen has had a much less visible profile and reputation in oil related programs – to the extent that several interviewees (including members of the university’s own staff) pointed out that the university had (perhaps deliberately) missed the boat. However, the lack of visibility or reputation disguises the contribution that the university has made, particularly through individual academics on the research side. The story of the University of Aberdeen is one of weak institutional responses juxtaposed with commitments by individual academics in a diverse set of disciplines (these individual level responses will be described in full in the research section below).

Indeed, there are more tales told at the University of Aberdeen about how the university rejected opportunities to get engaged with industry during the early years than those about the proactive roles it played. When there was a proposal to establish a postgraduate program in petroleum engineering in Scotland, Aberdeen was the most obvious candidate at the beginning. The university rejected the idea partly because of the expected short life of the oil and gas industry – and Heriot Watt took over that function. The chemist who proposed the program left the university and went to become the principal of Heriot Watt, where he actively supported the establishment of the Institute of Petroleum Engineering.

On the other hand, the University of Aberdeen did make at least one institutional commitment to oil-related education, establishing a small masters program in petroleum geology as early as 1970-71. This program grew from a base of 5-6 students to 20-25 students today. How the proposal to set up such a program came about within the university is not clear, given that the founder of the program, who had come from industry, found the university environment very academic and not very hospitable to industrial interests.

Indeed, geology is the only department to have developed a significant group of academics engaged with industry– with the majority of the academics in the department working with the oil and gas industry today. But even here the record is not consistent. The founder of the Petroleum Geology program left within a couple of years, and a world-renowned American petroleum geologist came from Bergen to take over the post. But oil-related activities were not well integrated into the department, and by the late 1980s it was in sufficiently poor health that it was almost closed. It was kept going in no small part because of the support of several oil companies– Shell, for example, contributed funding to recruit a professor. It was important for the oil industry to have a viable geology department in Aberdeen.

One academic remembers how the university regulated against him from participating in significant consultancy in the 1980s. And this reflected the mood of the university at the time. Working closely with industry was simply not an institutionally-accepted mandate or nationally-encouraged activity until recently (Hatakenaka, 2004.).

In the early 1990s the Scottish authorities hired Monitor, a Boston-based consulting company, to undertake a cluster study. One of the key recommendations made by Monitor was to strengthen university-industry linkages, which, as one former Scottish Enterprise executive pointed out, was never seriously addressed in the subsequent years, much to his regret. It was only in the late 1990s that the University of Aberdeen started to establish key physical facilities which were relevant to the oil and gas industry, such as the Ocean Lab and high temperature/high pressure facilities. Around 2000, the university started to make more conscious and visible moves to engage with the oil industry in education as well – as exemplified by its new hydrocarbon masters program for 15 students.

Robert Gordon has a tradition of being application-oriented – and has had constant and close relationships with the oil and gas industry. It first became active in providing survival training in the early days - something that was required by industry for safety. Given its critical need, the operation was continued until several years ago, when it was finally sold off to a private entity. Indeed, its staff reflects on how the University lost its focus on the oil industry in the mid 1980s, under a new principal who was not well disposed towards the oil industry. Whereas there were about 10 academics working with the oil and gas industry in the school of engineering in 1979, there are only 2 today. The lack of internal expertise has been offset by the use of external expertise accessed through its dense networks with the industry. RGU started its postgraduate program in petroleum engineering in the early 1980s. The program is still popular and attracts 100 students a year. In contrast to the early days, however, when the bulk of students were British (many of whom did not even have undergraduate degrees and so Robert Gordon had to be 'innovative' in recognizing their work experience as equivalent background for undertaking a postgraduate program), today most of the students are from overseas. RGU added two more masters programs in the late 1990s, but all of these courses are now managed by UNIVATION, the university's industry liaison company, seen largely as income generating professional development courses. Only a small proportion of the program is taught by inside academics, with the bulk of specialist modules taught by industry specialists.

6.2.3. Relationship with industry

One similarity between the two regions is the interest on the part of industry in involving educational and research institutions from the early days. There were tangible needs for local support in education and research. However, the different institutional responses reflect the different levels of engagement that institutions had in working with industry.

In UiS the proximity to the industry has been advantageous for both the industry and academia. In the defining years, the industry was represented in curriculum development committees. Personnel exchanges were extensive because the college was in great need of expertise. As the college matured and later transformed into a university, the direct influence exerted by the industry appears to have diminished. When the industry first entered the region, industry professionals were recruited to teach at the college. Today, the university often recruits teachers with degrees in basic science from other universities, and converts them to petroleum specialists. Firms from the oil and gas industry present themselves at career conferences and invite students to write masters theses.

The oil industry and regional interests have been represented on the Board of the University. Strategically, the university wants to take on a regional role and be part of the regional economic and social development process. This is also reflected in the composition of the board. Contrary to other Norwegian universities, the Board majority is comprised of external members. But the university's main contributions have been in teaching and research. In the words of Professor Svein Skjæveland, UiS: *"Our focus is on publications, not on developing new technology to be used in the industry. It is difficult to do both. We are academics and therefore we focus on producing papers and publications instead of being board members within the industry, becoming entrepreneurs or develop new "things". It is difficult for an academic to retain integrity and producing high academic quality research while at the same time being a businessman."*

In Heriot-Watt, a similar structure for seeking industry advice was set up at a program level, but there was no systematic involvement of industry in the institutional governing board. The University of Aberdeen has not developed systematic ways of working with industry. In a sense, the absence of such mechanisms is not overly surprising since the universities were already well established institutions in the 1970s when the oil and gas industry was born. It was much easier for UiS, which was born at the same time as the industry, to develop a viable partnership with it. RGU developed its own approach to working with the industry, capitalizing on locally available industry-based expertise in providing industry-relevant education programs.

6.2.4. Contribution in education

It is not easy to understand or contrast the contribution these institutions made in education. This is because the outcomes of education are intangible in the short term, and cause and effect are hard to disentangle in the long run.

Our interview results show a systematic difference in perception, however. Interviewees in Stavanger positively endorsed UiS's contributions in education, while those in Aberdeen tended not to see them or saw contributions from other universities as being more important. However, such differences in perception can arise simply by virtue of cultural differences or differences in perspectives. Some cultures tend to emphasize strengths, others tend to emphasize weaknesses. In a small, well-networked community, people may be less likely to criticize local institutions than in a diverse community. Employers in the UK, recruiting from over a hundred higher education institutions, may be less conscious of the specific roles of Aberdeen institutions than those in Norway where there are only five universities in the country. The fact that UiS has tangible petroleum related programs does not mean that recruitment from UiS in the industry has been systematically larger than that from Aberdeen University. It is possible that graduates from diverse disciplines entered the industry in less conspicuous ways.

For all these reasons, we can only make tentative conclusions – based on evidence from multiple sources - to test the strength of the arguments in terms of consistency. The conclusion we make is that UiS's contribution is likely to have been unique, in relation to other Norwegian institutions, in relation to the two Aberdeen institutions, and even in relation to Heriot-Watt.

First, the UiS has consistently attempted to fill a critical gap in the supply of trained personnel. Many of our interviewees contrasted the level of education of the oil and gas industry in Norway with that in the US and the UK. The Norwegian industry was able to recruit the brightest master's graduates in the country coming from a variety of disciplines in prestigious universities. The importance of UiS's three-year petroleum-related program at the outset lay in its ability to supply well-trained mid-level professionals/technicians to support the industry from below. Graduates from the UiS were known to be more application-oriented than the others: *"A lot of our people have a technical college as a foundation and have built upon that at the UiS to obtain a petroleum engineering degree"*.

Over time, as the UiS became first a University College and then a University by virtue of its track record and performance, its contribution shifted upwards, initially to masters level education and now to the production of Ph.Ds – all in application-oriented fields of critical relevance to the industry.

Table 6-4 shows the distribution of petroleum technology graduates at the masters and doctoral level amongst all the Norwegian universities and some of the university colleges. The production of graduates at the master's level in Norway oscillates around 250 graduates per year, with the UiS taking over the leading position from NTNU in 2000. The number of doctorates issued in the same technological fields is 10-20 PhDs per year, with NTNU playing a dominant role. However, statistics are somewhat misleading, since until 2005, when UiS was designated a university, many of its doctoral students had to receive their degrees from NTNU.

Table 6-3: Graduates in petroleum-related technological fields at Norwegian universities 1997-2000[37]

	1997	1998	1999	2000
University of Oslo				
- masters of science	10	10	10	10
- doctors	1	2	2	2
University of Bergen				
- masters of science	12	18	11	6
- doctors	0	2	2	1
Norw. University of Technology				
- masters of science	98	118	98	95
- doctors	6	10	10	4
University of Stavanger				
- masters of science	106	83	85	133
- doctors	2	5	1	2
TOTAL CANDIDATES	**235**	**248**	**219**	**253**

Both the university and industry testify that the UiS positioned itself between the traditional universities and the engineering colleges. The UiS added an applied perspective to the basic disciplines, and is regarded as having a greater application orientation than NTNU. UiS's proximity to the industry has been part of shaping its capabilities. Unlike NTNU, UiS has had the advantage of being less than a 10-minute drive from the majority of oil and gas related companies in Norway. That has resulted in a close dialogue when it comes to shaping and creating industry-relevant education programs and joint research projects. Further, proximity has enabled an extensive use of industry personnel in education through visiting professors and guest lecturers. In addition, students doing fieldwork for projects on various levels have been close to the source.

In the UK, the impact of individual universities in education is difficult to assess. Companies appear to have hired graduates from all over the country and from a variety of disciplines, with technical people recruited from geology and general engineering. It was perhaps also easy in the 1970s and the early 1980s for oil related companies to recruit graduates from diverse fields, given that graduate unemployment was a serious problem nationally. To the extent these companies were willing to mention particular universities which made important contributions to education, the names quoted were the usual suspects such as Heriot-Watt and Imperial. There were few observers in larger companies who were in a position to comment on recruitment from local universities given the fact

[37] Source: Karlsen et al. (2002); tables 4.2.2-3) (The table incorporates only candidates in geosciences, offshore and/or petroleum technologies

that most of them were on short-term assignments in Aberdeen in their career on international circuit. Smaller companies have more experience in recruiting locally, but they do not have a comparative or consistent experience to comment on the quality of their recruits. As one CEO of a technology-oriented SME admits, local engineering schools were perhaps more important for aspiring small companies, which could not hope to recruit graduates from outside the region. A survey of 192 SMEs carried out in 2000 showed that only 12% of SMEs felt that they had local support in research and technology, whereas over 38% thought they had local support in training and recruitment (MacKinnon et al, 2004).

Given the diverse undergraduate educational backgrounds of these recruits, postgraduate programs would have been important both for companies and for individuals as a means for specializing into the industry, particularly through the 1980s when the industry was expanding rapidly. And indeed, this is where we observe more institutional efforts in specialized programs.

At Heriot-Watt, the first petroleum related program was offered at the undergraduate level – but it was a quick and superficial modification of existing engineering programs. The real focus on the industry came about only with the introduction of a masters program in petroleum engineering, which grew rapidly from 20 to 30 in the 1980s and was receiving 400-500 applications a year. Today, the university says it has about 70-80 postgraduates and nearly 200 distance learners at any given time. The University of Aberdeen's petroleum related programs have never been large. Today, it has a small masters program in petroleum geology with 20-25 students and a new hydrocarbon masters program for 15 students. As noted previously, RGU was different in that its first contribution to industry was survival training for industry personnel. It has developed postgraduate programs in petroleum engineering and related fields since the early 1980s. The petroleum engineering program is still popular and attracts about 100 students a year.

Heriot Watt quickly built a considerable reputation within the oil industry and received many corporate-sponsored students from oil related companies. Robert Gordon's program was probably more important for individuals aspiring to develop stronger professional capabilities. Robert Gordon was 'innovative' in taking many British students who did not have bachelors degrees into their masters programs, based on their work experience which was regarded as equivalent to a bachelors degrees. However, in the 1990s the student composition changed dramatically, for both Heriot-Watt and RGU, from one dominated by domestic students to one of international students. It is no longer clear what educational role these programs play for the domestic population.

For small companies, the role of local universities was perhaps more significant – but at the undergraduate level. As one CEO of a technology-oriented SME admits, local engineering schools were perhaps more important for aspiring small companies, which could not hope to recruit graduates from outside the region. A survey of 192 SMEs carried out in 2000 shows that only 12% of SMEs felt that they had local support in research and technology, whereas over 38% thought they had local support in training and recruitment (MacKinnon et al, 2004).

It is not clear what role these programs played in helping 'anchor' the industrial capability to Aberdeen. They certainly appear to have played a role in helping existing industry in Aberdeen locate opportunities for professional development to ensure their competitiveness. Still, they do not appear to have been the engine of growth for the industry. The local programs could have played a role in the later phases of the industry, when oil and gas as a field of employment has been less attractive nationally, and as the aging of the industry workforce has become a significant issue. However, the local population in Aberdeen appears to have been as cool about the future of the industry as the rest of the country.

6.2.5. Contribution in research

The regional research and educational institutions have taken on different roles in relation to the research needs of the oil and gas industry. In Stavanger, RF was established explicitly to build a local research capacity, supported by the university. On a smaller scale, the university conducted user-oriented basic research as a prerequisite for later development of applied technology. Both Stavanger institutions report vigorous relations with the industry, a feature they share with other petroleum-related institutions in Norway. In the UK the most visible research role was played by Heriot Watt in Edinburgh and Imperial College in London. At the University of Aberdeen, a small number of individual academics from a diverse set of disciplines became intricately involved with the research needs of the industry, while RGU was more of a teaching institution with limited capacity for research.

6.2.5.1. Stavanger

Though RF is a public research institution, it has very little direct government funding (7% of turnover). The rest is generated through competition for industry-relevant projects and funding from the industry (50%), the Research Council of Norway and EU (25%) and regional sources (20%) Approximately 80% of RF's petroleum activities are industry funded and the major oil companies are the largest user group for RF's research activities. RF is the second largest research institution in upstream oil and gas in Norway after SINTEF in Trondheim. Even though the oil and gas related research institutions compete with each other for both private and publicly funded projects, there is a sense of logical distribution of areas of expertise. Table 6-5 gives an overview of the public R&D institutes in Norway and their technological oil and gas related focus areas.

Table 6-4: Public R&D institutes (2000)

Name	Main location	O&G researchers	Total employees	Technological O&G focus areas
Christian Michelsen Research (CMR)	Bergen	51	110 (CMR group)	• Instrumentation • Advanced visualization • Gas safety • Fuel cell technology
Institute for Energy Technology (IFE)	Oslo	60	520 (IFE Group)	• Reservoir tracer studies • Multiphase transport • Corrosion control • Control room engineering
Rogaland Research (RF)	Stavanger and Bergen	85	238 (RF group)	• GEO modelling • Improved oil recovery • Drilling, well and reservoir modelling • Well construction • Risk management, • New recovery technology • Environmental control
SINTEF Petroleum Research	Trondheim (departments in Stavanger and Bergen)	107	1800 (SINTEF group)	• Basin modelling • Drilling and well construction • Well and production technology • Multiphase flow technology • Formation physics • Reservoir technology • Seismic • Solutions oil and gas

RF was established in 1973 by the regional authorities. Initially, it was meant to be the research arm of the college – a place where college personnel could undertake their research activities. The original intention was to conduct research on the social impact of the emerging oil industry, but RF soon started developing engineering capabilities, as applied research needs from industry increased, and as government kept on pushing industry to work with domestic partners, most notably through goodwill agreements.

Many college employees worked as part-time researchers at RF. Some RF employees left RF to become permanent staff at the UiS. The relationship between the university and RF continues to be close. By January 2006, RF and parts of UiS will consolidate to create Norway's largest research company within the upstream oil and gas industry. The new company, IRIS (International Research Institute of Stavanger), will unify the capabilities residing in these two separate institutions today.

RF's petroleum department was established in 1976. Part of the reason was that petroleum research would support and leverage the ambitions to establish a civil engineering program at the college. The mutual benefits of a coordinated effort by the college and the research center were thus recognized from the very beginning.

For RF, the most important event was the building of the Ullrig full-scale drilling site. Shell and Statoil financed the facility and Exxon funded the first major drilling-related research program (Integrated Drilling System). With this unique facility, RF was able to develop key knowledge and research capacity in drilling and well handling.

The use of Ullrig has changed over time. It first served as a critical research-support facility around which RF developed its own capabilities, enabling it to become a national hub. Several innovations entered the market during the 1980's and 1990's as a direct result of research activities at Ullrig. After the termination of the goodwill period in the latter part of the 1990s, the willingness to invest in R&D among the operators decreased rapidly. Since then, Ullrig was transformed into an equipment testing site. Since the cost of testing new technologies at Ullrig is much lower than testing them offshore, the facility has proved to be vital in advancing the rapid development of drilling equipment.

In an interesting contrast, the equivalent drilling facility in Aberdeen was developed in the Offshore Technology Park, but without a cluster of research capacity around it. Scottish Enterprise eventually sold it to Weatherford when it became obvious that after the initial round of use, it was underutilized.

In addition to its intellectual capacity and leading position within drilling, RF has positioned itself as a leader in improved oil recovery (IOR). In 2002, the International Center for Improved Oil Recovery (COREC) was established. A long-term contract was signed with ConocoPhillips that secured financing of IOR-research at RF for at least ten years. A team of 10 researchers from RF and UiS is currently undertaking IOR-research.

RF has captured a major share of the Government sponsored PETROMAKS program, presently participating in programs exceeding NOK 100 million in value. The grants are channeled through the Research Council of Norway, arranged as a 50/50 partnership with industry.

Until recently, RF commercialized its research results only to a limited degree. The first attempts were made in the mid-90s as a response to the repeal of the goodwill agreements and industry's lack of willingness to invest in research. Commercialization efforts have since then gradually increased. RF started to develop, test and commercialize specific research-based products. However, it is only recently that there has been a significant increase in the number of spin-off companies coming out of RF (3-5 every year). Today, 20 spin-off companies are in the portfolio of RF's holding company RF–Forskningsinvest. Intellectual property has become an increasingly important income source for RF. The CEO of RF concludes: *"RF has taken the role as a knowledge agent. We produce new knowledge, conduct research and perform testing. We educate people and develop new* *technology for the industry. We have always done that and I can't see that it will change in the nearest future."*

This does not mean RF had not produced commercializable technology in the past. On the contrary, RF's history is peppered with anecdotes of companies that sprung out of RF's research, but without the formal involvement of RF in actual company formation. The petroleum lab, which was the first lab in RF, was eventually taken over by an analyst from Phillips and turned into the company, West Lab. Or later, with the Ullrig facilities, RF developed a number of technologies related to drilling, including the steering system for the automated drilling rig, which in turn led to a start-up company called Hitec. Hitec combined the results of what Exxon, Siemens and RF did, and developed the steering system for the automated drilling rig. Jon Gjedebo, a regional champion of entrepreneurship, took these results into Hitec and made the company a world leader in automated drilling concepts. Hitec was later bought by National Oil Well of Texas. In both cases, even though these start ups were based on RF developed technologies, RF did not play any role in company formation, simply because RF did not see this as its role.

The end of the goodwill period led to other revised strategies at RF in addition to commercialization. The impetus to go abroad grew stronger. Close relations developed with Petrobras within HPHT (High Pressure / High Temperature) and with Agip, which became a large customer for applied products and services.

RF also has research groups unrelated to petroleum engineering. The Centre for Social Research employs approximately 40 researchers and carries out various research tasks on, for example, safety and the work environment, organizational change and development, the use of differentiated contracts, learning and knowledge transfer. The role of the oil and gas industry in regional development has been repeatedly studied. The research is sponsored by the Research Council of Norway, NPD and the industry. The Center for Environmental Research in Aquatic Environment, which employs 50 scientists and engineers, carries out research for oil companies, land-based industry, the aquaculture industry, and governmental institutions in Norway and EU.

Although tightly coupled, RF and UiS have played different roles with respect to industry. UiS has tended to focus on education and long-term research involving academic publications, while RF has been the central player orchestrating joint industry projects, and has often been the source of commercializable ideas and technological innovations[38].

One example is the real-time modeling of well control. For many years, RF has been developing numerical models simulating physical processes taking place when drilling a well. The challenge is having control over the well when drilling. Several of these numerical models are now incorporated in operations management software called Drillbench. Well and drill data are utilized as input into this software tool enabling improved management of drilling operations. Drillbench predicts what is about to take place in the process before it happens. So, by feeding the simulator with data it is possible to predict mistakes and failures before they take place and therefore tp avoid them. The

[38] Svein Skjæveland, instrumental both at RF and UiS

manager of RF Petroleum explains: *"Over the years our deliveries to the industry have been substantial. We have delivered basic research, applied research, test facilities and commercialized products and services. This has been physical products, software products and new working processes"*.

RF has evidently played a role as an intermediary between academia and industry. RF has often served as a coordinator of joint industry projects that include a wide range of partners – including universities and oil and service companies. According to the industry, such projects have proven cost effective as several contributors share the costs. From an industry perspective, RF was a welcome partner, as it often helped bring in public funding support for joint research.

Contract research emerges through at least two mechanisms. The most obvious comes into play when industry approaches the research institute with a problem or a challenge. It also works the other way around, however, when researchers familiar with industrial challenges suggest ideas with potential economic and/or environmental impact to the industry. These ideas are typically a combination of basic knowledge used in novel ways to resolve challenges. RF has also been a link between outside universities and research institutions and regional industry. As manager of joint industry projects, RF coordinates knowledge from several sources (universities, research institutions and industry) to develop applications for research. RF has played the role of mediator or knowledge broker in managing joint industry projects, and has developed specialist expertise which is complementary to the knowledge base of individual firms or that of academic institutions, especially related to improved oil recovery.

RF has also contributed to regional competence building and the production of researchers. Most RF researchers are recruited from basic disciplines at the university. They are exposed to industrially-relevant research at RF, and then leave mainly for industry and sometimes for universities or other research institutes in their 20's or 30's. RF's high average turnover of 15-20% means that its employees come and go – from universities to industry, and back to universities. In this way it has facilitated knowledge mobility between academia and industry. Why do researchers leave for the industry? The size of the paycheck is evidently one reason. The oil and service companies may also offer exciting research venues.

Many informants stress the importance of proximity. In so doing, they mean the physical closeness of the industry and the research institutions. This proximity partly explains the UiS's responsiveness to the needs of the industry and its more applied focus than the traditional universities. Proximity also contributes to the tendency to collaborate with people you already know. Concretely, we note that research contracts are often awarded to the alma mater of the decision maker. In a similar vein, RF takes advantage of former employees. They may award contracts directly to individual researchers known for their expertise, but also from personal relations. In other words, social proximity is just as important as geographical nearness. In both instances, search costs are reduced and expectations more precisely conveyed. Even in a truly global and market based industry, the social capital is decisive.

6.2.5.2. Aberdeen

Heriot Watt is one of the universities most frequently mentioned as a partner or a player by industrialists. Its institutional resourcefulness in developing deep relationships with industry was certainly one reason that enabled this to happen. Less visible but important ties were there for certain individual academics at the University of Aberdeen throughout the period. Through the 1980s, these research groups or individuals appear to have had little problem in getting funding, mainly from large oil operators such as BP and Shell. Since the 1990s, their role appears to have changed, mainly because of the restructuring in the industry, with oil companies playing much less proactive roles in technology development.

At the University of Aberdeen, there has not been much institutional level emphasis on building oil and gas related capabilities, as discussed earlier. However, there have been individual academics who became seriously engaged with the industry, often leading to sustained relationships. In economics, a small group of economists specialized in petroleum related economics, leading to a spinout company (AUPEC). Professor Alex Kemp is today a world authority on petroleum economics, specializing in the impact of government policies upon the oil industry, and has become an international name in the field, with some of his former research associates also working as independent and international consultants (McKay). In zoology, a professor started studying the impact of offshore platforms on marine life, which also led to a small but internationally successful spinout company. In geography, one professor (Keith Chapman) maintained a loose but sustained interest in the economic impact of the oil industry on the region, which led to a revival of concentrated research work in the late 1990s through the recruitment of a couple of younger researchers (Andrew Cumbers and Danny Mackinnon). Other individuals with linkages to the oil and gas industry include a psychologist and a management professor.

Individual stories about how relationships developed in and around Aberdeen University indicate the role of chance encounters, where proximity played a significant role. A biologist recollects how his colleague was recruited into examining the effect of platforms and other offshore structures upon marine life. He also reflects how it was his research assistant who managed to get into contact with an oil industry executive, which ultimately led to his getting significant funding from the industry. An SME researcher tells a story about how he bumped into a university official at a meeting, which led to a relationship which involved monthly meetings. In contrast, Heriot Watt, which also did benefit from some of these chance encounters as it is only 2 hours away, made constant and substantial effort in following up and in maintaining industrial linkages.

However, examples of strong ties in technological fields other than geology were hard to find. The three high-tech and specialized small companies we interviewed all indicated their needs and desires to work with universities. They all recognized the need to be associated with some research capacity that they cannot afford to have internally. For them, private research bodies (such as Caltec or AEA) are well beyond their reach because of the high costs associated with their services. In this view local universities could be a much cheaper source of expertise – though all of them found universities in Aberdeen difficult to work with, at least partly because of what they regarded as the universities' aggressive position on intellectual property rights.

To develop a comparative perspective on the contributions made by these universities in research, we examined two types of indicators related to industry-relevant research publications; papers published in the Society of Petroleum Engineers (SPE); and Petroleum Abstracts (PA).

The number of papers published in the Society of Petroleum Engineers (SPE) is a quantitative measure of application-oriented research relevant to industry (see Table 6-6.) While SPE papers tend not to capture fundamental scientific research, and while their coverage tends to center on E&P-related petroleum engineering and technology and does not extend to other fields such as geosciences (most notably for the University of Aberdeen, geology) or petroleum economics, they constitute one of the most important bodies of codified knowledge for the industry.

Table 6-5: SPE-papers from key research institutions in Norway and the UK, 1990-2004

	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

We note that the two research institutions in Stavanger published 308 papers over this period, compared with 70 for the corresponding institutions in Aberdeen. The pattern of authorship is also different. The majority (around 2/3) of the papers from University of Stavanger and RF are 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 are written by their own faculty alone. The majority of the papers from the University of Aberdeen relate to management issues, such as safety, health, and sustainability challenges, reflecting their impact especially after the Piper Alpha accident. This pattern differs from the papers from the other institutions, which focus on "harder" technology issues.

The publications from Heriot Watt (and Imperial College to a lesser extent) dwarf those of the two regional institutions in Aberdeen as well as all four institutions in Norway.

However, it is perhaps fairer to compare Heriot Watt's total to the combined total of the two institutions in Stavanger, since the latter were developed as twin institutions in education and research. Here there is close to equivalence. Also, the Stavanger institutions remain more 'collaborative' than Heriot Watt; two thirds of the papers were co-authored in Stavanger as compared with just under a half in Heriot Watt.

The two Stavanger institutions can also be compared with the two institutions in Trondheim. Here, we might have expected to find that SINTEF 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 1800 employees, compared with 238 at RF). While the pattern of collaboration is similar in Trondheim, with about two thirds of the papers coauthored with authors from other institutions, the total number of publications is less than 60% of that of the Stavanger institutions.

The Norwegian institutions appear to be more collaborative than their counterparts in the UK. Table 6-7 gives a more detailed breakdown of collaboration patterns.

Table 6-6: SPE-papers written in collaboration with others, 1990-2004 (% of total papers in parentheses)

	UiS	RF	SINTEF	NTNU	UofA	RGU	Heriot Watt	Imperial College
Co-authored *solely* with higher education and/or research institution	21 (21%)	36 (17%)	20 (21%)	17 (22%)	2 (5%)	2 (7%)	30 (10%)	32 (20%)
Co-authored *solely* with industry	27 (27%)	71 (34%)	30 (31%)	30 (39%)	18 (40%)	8 (31%)	104 (34%)	28 (18%)
Co-authored with *both* industry and higher education/research institution	15 (15%)	26 (13%)	13 (13%)	11 (14%)	0	0	10 (3%)	5 (3%)
Total	**63**	**133**	**63**	**58**	**20**	**10**	**144**	**65**

The numbers indicate stronger collaboration in the academic community in Stavanger than Aberdeen. In Stavanger, 6% of the papers were written in collaborations between RF and the University and nearly 11% by these two institutions in co-authorship with other academic institutions (national and international). Altogether, 20% of the papers were co-authored solely in academic partnerships – regardless of local co-authorship. In Aberdeen, only 3% of the papers were collaborations between the University of Aberdeen and Robert Gordon University and a total of 5% were the product of all kinds of academic collaboration. Researchers in Aberdeen prefer to collaborate with the industry (40%), a similar proportion to that at Heriot Watt (37%), and higher than at Imperial College (21%). At the four Norwegian institutions, between 42% and 53% of papers were written in collaboration with industry. In general, the patterns of co-authorship suggest that Norwegian researchers may be more collaborative across organizational boundaries than their UK counterparts.

Petroleum Abstracts (PA), a database developed by the University of Tulsa, provides a more comprehensive measure of research contributions covering a broader range of fields relevant to the industry, including geosciences, social sciences and economics. In addition, while the SPE database focuses on applied upstream technology, the PA database covers the whole spectrum of publications from basic science to applied technology. Table 6-8 shows that the contribution from the University of Aberdeen is much greater when the wider range of subjects 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, whereas on the narrower measure of SPE publications their contribution was less than 60% of the Stavanger institutions.

Table 6-7: Number of Publications in Petroleum Abstracts (1965-2005)

Institution	Number of references 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 that the Stavanger institutions' research contributions have been significant and are more focused on application-oriented research in petroleum engineering fields than that of the University of Aberdeen (or indeed SINTEF/NTNU or Imperial College). They also show that Heriot Watt has made roughly equivalent contributions in similar fields. 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.

These results suggest that even though the University of Aberdeen has not been actively responsive to the industry needs as an institution, individual academic responses have been significant. It also suggests that the nature of academic contributions from local institutions in the two regions may be significantly different, with systematic and structured ties in a narrower set of fields in Stavanger, and dispersed ties in a wide range of fields in Aberdeen.

Concluding remarks: Local innovation capabilities

In this section the local innovation capabilities of the two regions were compared. Stavanger amassed technological capabilities deliberately and systematically in key institutions. Statoil and NPD are primary examples. In the case of Statoil a global operator emerged from nothing to surpass many other global operators in its technological capabilities. RF and UiS have also been specifically and systematically developed to create applied research and education capabilities that are tightly linked with the industry.

In contrast, Aberdeen's technological capabilities appear to be much more diverse, with greater numbers of companies in each sectoral category, and also seem less structured or consciously built than in Stavanger. The technological champions of the past, BP and Shell, are downgrading their technological presence in Aberdeen, with independents and their service/supply partners taking on greater prominence in less R&D intensive but nonetheless important innovations relevant to brownfields. Aberdeen's universities have related to industry in less visible ways, and the extent to which expertise was developed depended more on serendipity and the initiative of individual academics than on institutionally orchestrated plans. And yet, our preliminary analysis shows that their research contributions could have been as significant, covering a wider range of fields than in Stavanger.

This section also suggested that collaboration is more prevalent in Stavanger than in Aberdeen. Stavanger's small niche companies appear more closely linked to operators such as Statoil and Norsk Hydro, as well as to local research institutions, than their Aberdeen counterparts. Stavanger academics and researchers appear to engage more readily in collaboration across organizational boundaries. In the next section, the different patterns of innovation are explored further through an analysis of patenting.

7. Patenting in Stavanger and Aberdeen

In this section we analyze patenting behavior in Stavanger and Aberdeen. The limitations of patents as measures of innovative activity are well known. On the one hand, far from everything that is patented will turn out to have real economic value; on the other hand, firms have multiple strategies for protecting and managing their intellectual property and patenting is often not the primary one. Comparing patenting data in the same industry in two different regions can nonetheless reveal useful insights.

Patents, when granted, recognize the inventor (or inventors) and issue to an 'assignee', or owner. For inventions by employees of corporations and research institutions, the assignee is usually the employer, and the assignee typically plays a major role in the patenting process.

Inventors and their sponsors around the world seek patent protection for their discoveries both in their home countries and overseas. Overseas patenting is most common in the U.S. The U.S. patent database reports the addresses of both inventor(s) and assignee(s) for all patents granted in the U.S., and this information is useful in ascertaining the location of innovative activity. Broadly speaking, the inventor address provides an indication of where the inventive activity was carried out, while the assignee address is indicative of the source of financial support for the inventive activity.[39]

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 in the greater Aberdeen area. 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 greater Aberdeen. We then carried out the same search for inventors and assignees in the greater Stavanger area.[40]

The results are shown in Table 7.1. We identified a total 756 U.S. patents with at least one inventor based in greater Aberdeen, and 177 patents with at least one Aberdeen assignee. We identified 307 patents with at least one greater Stavanger-based inventor, and 251 patents with at least one Stavanger assignee. These are not enormous numbers. By comparison, many individual corporations are routinely granted more than a thousand

[39] The inventor address reported in the US patent database may refer either to the residence or to the place of work of the inventor, and there is no way to tell which. However, since in most cases the two locations are in reasonably close proximity, the inventor address information is not a bad proxy for the location of the actual work. The assignee address for corporate patents is generally the headquarters location of the firm. For large, multi-divisional and/or multinational firms, the address reported sometimes refers to the headquarters of the parent, and sometimes to the headquarters of the local affiliate.

[40] 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.

U.S. patents each year.[41] Still, the numbers are large enough to gain some insight into patterns of inventive activity in the two locations.

Table 7-1: 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)

The difference is particularly intriguing given the reputation of Stavanger as a technologically driven center of the oil industry. Why should Aberdeen-based inventors have been granted more than twice as many patents as their counterparts in Stavanger? One possibility is that there is a difference between the two countries in the propensity to patent. If individual inventors and/or firms in one country are more likely to seek patent protection, or, more specifically, are more likely to seek U.S. patents, then this would contribute to overall differences in the rate of patenting. There is in fact considerable indirect evidence to support this hypothesis. For example, there appears to be a general tendency for UK inventors in all fields to seek U.S. patents at a higher rate their Norwegian counterparts.[42]

A second possibility is that there may be differences between the two regions in their orientation towards intellectual property rights. Many of our interviewees suggested that there is a systematic difference between Stavanger and Aberdeen in this regard. In Stavanger, collaboration and sharing of knowledge was claimed to be the norm, while that was less so in Aberdeen.

A third contributing factor may be that U.S. firms – which presumably have a higher propensity to patent in the US than non-American firms – appear to be playing a more important role in inventive activity in Aberdeen than in Stavanger. Table 7.2 shows the

[41] IBM, the most active patenter in the US, was granted more than 3000 patents in 2004.
[42] In 2001, 3965 US patents were granted to inventors located in the UK, and 265 patents were granted to Norwegian inventors. (National Science Foundation, *Science and Engineering Indicators – 2004*.) Normalizing these figures to account for the difference in the scale of innovative activity in the two countries, using reported R&D expenditures, U.K. inventors in all fields received an average of 170 patents per billion dollars of R&D expenditure in the UK in that year, while their Norwegian counterparts received 95 patents per billion dollars of R&D expenditure in Norway.

location of the assignees for the Aberdeen-based and the Stavanger-based inventions which were granted U.S. patents.

Table 7-2: 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-BASE 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%)

*"Aberdeen-based inventions" are defined as those for which at least one of the inventors is based in greater Aberdeen; and similarly for "Stavanger-based inventions".

The table shows that non-local firms – and especially U.S. firms – are more active in sponsoring inventive activity in Aberdeen than in Stavanger. 80% of Aberdeen-based inventions were assigned to non-local firms, compared with 52% in Stavanger, and nearly half of the Aberdeen-based inventions were assigned to American firms. In absolute terms, 366 patents involving Aberdeen-based inventors were assigned to American firms, compared with just 86 involving Stavanger-based inventors.

Parenthetically, the table also provides additional support for the finding discussed elsewhere in this report that the Norwegian oil and gas industry is more heavily concentrated in Stavanger than is the case for the UK industry in Aberdeen. Of the 206.5 patents involving Stavanger-based inventors that were assigned to Norwegian firms, 71% (146) were assigned to firms located in Stavanger itself. By comparison, only 41% (153 out of 370.5) of the UK assignees for Aberdeen-based inventions are located in the Aberdeen area.

A major reason for the concentration of assignees in Stavanger is the dominant role of Statoil, which is headquartered in Stavanger. As Table 7.3 shows, Statoil accounted for far more patents involving Stavanger-based inventors than any other organization, Norwegian or foreign. In fact, Statoil alone was assigned nearly 27% (81.5 out of 307) of all such patents. Table 7.3 also shows that Aberdeen-related inventive activity generated considerably more US patents for the three major American integrated service firms than the corresponding activity in Stavanger.[43]

[43] It is important to note that the data in Table 7.3 do not reflect subsequent merger/acquisition activity. The table specifies the identity of the assignees at the time that the patent issued.

While Aberdeen-based inventors have accounted for a larger number of US patents than their Stavanger-based counterparts, the opposite is true when it comes to assignees in the two locations. A total of 251 patents (from all locations) have been assigned to Stavanger-based firms, compared with 177 assigned to Aberdeen-based firms. Table 7.4 shows that one reason for this is the more extensive geographic reach of Stavanger-based companies. Patents issuing to Stavanger assignees have drawn on the work of a more widely dispersed group of inventors than is true of their Aberdeen counterparts. The difference is especially pronounced for inventors located elsewhere in the home country as well as elsewhere in Europe.

The patent data also contain information about the main technical fields in which inventive activity has occurred in the two regions. Table 7.5 shows that the most active areas of patenting in Aberdeen have been: (1) well completion; (2) drilling technology; (3) production technology; and (4) subsea technology. In each of these fields, Aberdeen-based inventors have obtained more patents than their Stavanger counterparts. The only field in which more patents have been obtained by Stavanger-based inventors than their Aberdeen counterparts is seismic technology. The most active area of patenting in Stavanger has been subsea technology.

Finally, individual patents may also include citations to the scientific and technical literature. We used this information to explore the relationships between the oil and gas industry and the research community in the two regions. We found that the share of patents citing the scientific and technical literature is roughly the same in the two regions. Of the 756 patents with at least one Aberdeen-based inventor, 108 (14.3%) included at least one such citation. And of the 307 patents with at least one Stavanger-based inventor, 42 (13.7%) included at least one such citation. For both sets of patents, the most extensively cited publications are those of the Society of Petroleum Engineers (20.2% of all citations for the Aberdeen patents, and 15.2% of all citations for the Stavanger patents.) In both regions, too, there has been a significant increase in the use of scientific and technical citations in patenting since the late 1990s. The overall numbers are smaller and the year-to-year fluctuations are larger in Stavanger, but the trend is clear there, as it is in Aberdeen. Also, for both Stavanger and Aberdeen-based inventions, patents granted to U.S. assignees are more likely to include citations to the technical literature than those granted to domestic assignees (see Tables 7.6 and 7.7). Finally, the likelihood of citations to the literature varies by technical field. In general patents in the field of seismic technology were most likely to include such citations.

The preceding paragraphs are suggestive, but certainly not definitive. More research is needed both to explain the differences in patterns of patenting between the two regions and to understand their significance to overall performance.

Table 7-3: Assignees with 4 or more US patents on inventions involving at least one Aberdeen-based inventor or at least one Stavanger-based inventor (through June '05)*

PATENTS WITH AT LEAST ONE ABERDEEN-BASED INVENTOR		PATENTS WITH AT LEAST ONE STAVANGER-BASED INVENTOR	
Assignee Name	**No. of patents**	**Assignee Name**	**No. of patents**
Baker Hughes Incorporated	64	Statoil	81.5
Weatherford/Lamb, Inc.	56	Weatherford/Lamb Inc.	18
ABB Vecto Gray Inc.	54	Baker Hughes Corporation	17
Halliburton Company	33	Halliburton Company	15
Smith International	28	Schlumberger Technology Corporation	8
Schlumberger Technology Corporation	22	Phillips Petroleum Company	6
Expro North Sea Limited	21	Bakke Technology AS	6
British Petroleum Company Limited	17	Smedvig A/S	6
Coflexip	16	Hitec A.S.	6
Vetco Gray Inc.	15	Exxon Production Research Co.	5
Specialised Petroleum Services Group	13	Engineering & Drilling Machinery AS	5
Hunting Oilfield Services (U.K.) Limited	12	Triangle Equipment AS	4
Petroleum Engineering Services Limited	10	Geco AS	4
United Wire Limited	9	Transocean Petroleum Technology AS	4
FMC Technologies, Inc.	9		
Dresser Industries Inc.	8		
Andergauge Limited	8		
Downhole Products PLC	8		
Texaco Limited	7		
M-I L.L.C.	7		
Petroline Wellsystems Limited	6		
SPS-AFOS Group Limited	6		
Well-Equip Limited	6		
Shell Oil Company	6		
Rotech Holding Limited	6		
Stolt Offshore AS	5		
Camco International	5		
Petroline Wireline Services Limited	5		
Cooper Cameron Corporation	5		
Baker Oil Tools Inc.	4		
Reeves Wireline Technologies Ltd.	4		
Varco I/P, Inc.	4		
Red Baron	4		
Tuboscope	4		
Exploration & Production Svcs (North Sea) Ltd.	4		
Ocre (Scotland) Limited	4		
BG PLC	4		

*Note: The table specifies the identity of the assignees at the time that the patent issued, and does not take account of subsequent merger/acquisition activity.

Table 7-4: Location of inventors for patents with Aberdeen and Stavanger Assignees (through June '05)*

Location of inventor:	Aberdeen assignees (No. of patents)	Stavanger assignees (No. of patents)
Local	128 (72%)	89 (35%)
Inside Country	34 (19%)	121 (48%)
Europe	7 (4%)	27 (11%)
Global	8 (5%)	14 (6%)
Total	**177 (100%)**	**251 (100%)**

* For multiple-inventor patents, the reported address is that of the inventor who is furthest distant from Aberdeen or Stavanger

Table 7-5: Distribution of patents by technical field for inventions with at least one Aberdeen-based inventor or at least one Stavanger-based inventor

Technical field:	Aberdeen-based inventions (No. of patents)	Stavanger-based inventions (No. of patents)
Seismic technology	3 (0.4%)	17 (5.5%)
Formation evaluation	32 (4%)	13 (4%)
Drilling	184 (24%)	37 (12%)
Well completion	194 (26%)	64 (21%)
Production	140 (19%)	69 (22%)
Subsea technology	152 (20%)	88 (29%)
Other	50 (7%)	19 (6%)
Total	756 (100%)	307 (100%)

Table 7-6: Frequency of citations to the scientific and technical literature in U.S. patents with at least one Aberdeen-based inventor, by location of assignee

Location of assignee	Number of patents	Number of patents with citations to the scientific/technical literature	Share of total patents with citations	Total number of citations	Average citations per patent
UK	370.5	32.5	8.8%	64.5	2.0
US	366.5	69	18.8%	348	5.0
All	756	108	14.3%	426	3.9

Table 7-7: Frequency of citations to the scientific and technical literature in U.S. patents with at least one Stavanger-based inventor, by location of assignee

Location of assignee	Number of patents	Number of patents with citations to the scientific/technical literature	Share of total patents with citations	Total number of citations	Average citations per patent
Norway	206.5	19	9.2%	53.5	2.8
US	86	21	24.4%	94	4.5
All	307	42	13.7%	151	3.6

8. Industrial development processes

In the previous two sections, we described the local innovation systems which developed in the two regions. In this section, we focus on how these systems developed. To do so, we refer back to the conceptual model presented in the first section, which suggested that the industrial development of the regions could be described in terms of four more or less sequential processes, each describing a different stage in the relationship of the local industrial agglomeration to the international oil industry. The first stage involved the jump-starting of the industry through the **localization** of technical and industrial capabilities by foreign firms. In the second stage, specialized knowledge and technology continued to flow into the two regions, but local industrial capabilities began to be **upgraded** and **deepened** in part through imitation and learning, and over time more of the products and services required by the industry were developed and supplied within the region itself. The next stage of development, in which local capabilities become competitive in other markets, either through **internationalization** or **diversification,** is just now underway. And the final stage, the **delocalization** of these capabilities as the physical resources dry up, is still a hypothetical in the two regions. Indeed, it is the desire to avoid such an outcome that is the primary motivation for the present study.

Localization

How did the two regions attract key foreign companies as well as other organizations to the locality? In this section, we describe the process by which Stavanger and Aberdeen achieved their status as oil capitals. While both regions managed to establish significant agglomeration dynamics around the oil and gas industry, there were significant differences between the two, with Stavanger attracting a broader range of institutions than Aberdeen.

8.1.1. Establishing the oil capital: Stavanger

It was by no means self-evident that the Stavanger region should become the oil capital of Norway. The title was explicitly contested by a number of cities along the coast from Kristiansand in the south to Trondheim in the north. The first critical step was to attract key bases of oil companies – to offer offices and warehouse facilities, service and repair shops – which in turn could help attract other suppliers to the emerging industry.

The first exploration rig commenced drilling on the NCS on July 19, 1966. The first round of concessions to explore had been announced in May 1965, after Exxon, Shell and Phillips had initiated seismic examinations in 1962. As one of the conditions, the Norwegian authorities required that the exploration activities should be carried out from supply bases in Norway and through a Norwegian subsidiary. However, the authorities did not spell out where those bases should be established.

The mayor of Stavanger, Arne Rettedal, ran his own construction company and was accustomed to acting on opportunities and making quick decisions. With the traditional canning industry in sharp decline, he realized that the region was in urgent need of a new industrial footing. He joined forces with a local ship owner, Thoralf Smedvig, who was also politically active through his involvement in the same party. Smedvig was internationally oriented as well as a local booster. He had built a hotel of international format, Hotel Atlantic, established Stavanger Golf Club, and had been involved in building an indoor skating and ice hockey rink. He was in position to offer the local government the necessary real estate for oil-related supply bases and, coincidentally, sports activities that were attractive to Americans.

Exxon had established Esso Exploration Norway to manage its exploration activities, and assigned an American geologist, Richard J. Loeffler, to find a suitable location for a supply base. Loeffler traveled along the coast from Mandal in the south to Bergen. In Stavanger he met with Thoralf Smedvig, who presented a property including a shipyard, a mechanical workshop and a quay structure. Loeffler thought the property was suitable as a storage site for drill pipes, cement and drilling mud. Esso established its base in Stavanger and welcomed its first drilling rig, Ocean Traveler.

The next company was the Phillips group. Initially Phillips considered a property in Farsund, 100 miles south of Stavanger that was owned by Aker. Around that time, the mayor of Stavanger visited Phillips in New York to acquaint himself with the company's plans for Norway. He was informed that Phillips was not only concerned about base properties, but also about other key facilities, such as schools, housing, culture, and communications. Once the mayor became aware of these factors he moved quickly. The first manager of exploration for Phillips, Alfred Crump, and his family, were greeted by the mayor at the Stavanger airport. Hotel Atlantic became his first address and his children were enrolled in a Norwegian school. Regional initiatives and leadership were decisive in attracting the first oil majors. The regional authorities quickly responded to the needs of the emerging industry. A temporary American school was established as early as the fall of 1966. New housing areas were developed in record time. A completely new area, the "Oil hill", was developed to house the first American families.

At that time, comprehensive subcontracting was the norm for the oil majors globally. The American oil companies thus invited their traditional partners to the North Sea to carry out drilling, well activities, diving and geological surveys. These firms[44] naturally clustered around their customers. Subsequent oil companies flocked around the first movers because the exploration and production of oil fields required continuous coordination between the leading operator and other licensees on often very complex issues involving ownership rights and obligations, development strategies, and so on. Geographical proximity was important in these matters, and the Stavanger region quickly became the home of operations related to exploration.

[44] Baker Oil Tools Ltd.(drilling and production equipment), Halliburton Manufacturing § Service Ltd. (cementation and well testing), Moran (drilling), Dowell Schlumberger (well service, cement)

Between 1966 and 1969, 29 exploration wells were drilled without success. In the summer of 1969, Shell and Elf were in the process of withdrawing. The Phillips group had the same intention. They rented “Ocean Viking” on a fixed price contract and decided that they might as well drill another well, on block 2/4. This is how they discovered the first oilfield on the NCS, Ekofisk, whose gigantic size was to transform the fortunes of Phillips. Ekofisk production started in 1971, and the Stavanger supply bases prospered.

Until then, the new industry had had limited regional impact. Relatively few Norwegians were involved. In the fall of 1971, 1500 persons were employed in the oil sector, including about 300 Norwegians. No Norwegians occupied key positions. The Norwegians worked at the oil bases Norsea and Norsco. The American oil companies used internal labor markets as mechanisms for career advancement. New employees - including Norwegians - were recruited at the bottom of the pyramid without formal qualification requirements. The employers wanted to mold their workers to the culture of the firm and to develop the prerequisite attitudes and work ethic. On-the-job training was the prevailing method of knowledge transfer.

There was intense lobbying and competition between local authorities in the period leading up to the Norwegian government’s decisions about the location of NPD (Norwegian Petroleum Directorate) and Statoil. The local government of Stavanger, the county of Rogaland and the parliamentarians from Rogaland worked closely together. The Stavanger region already had a significant concentration of oil bases and the local government offered new industrial areas. The local shipyard, Moss Rosenberg (later Kvaerner and later still Aker Kvaerner), which specialized in LNG tankers, had already established itself as a supplier to the oil industry, albeit on a small scale. The Rogaland politicians’ main argument was the value of concentrating the oil business in one place. They argued that by concentrating the knowledge base, the industry could develop a greater capacity to address the demanding requirements of the North Sea. The state’s oil company, Statoil did not have internal expertise about the industry and needed to learn from the international oil companies. Proximity to other oil companies made sense. Similarly, the NPD would greatly benefit from proximity to the oil companies it was charged with regulating. Other arguments for Stavanger included a wide range of factors including proximity to oil fields, local government capacity to provide offices and housing, availability of industrial properties, an American school, hotel capacity, an international airport, an oil refinery as well as educational programs in petroleum technology at the regional college.

The location of NPD and Statoil was a major political decision. A dedicated Localization Committee was set up and recommended Stavanger as the best site for both of them to the Parliament. Some argue that the primary reason for Stavanger’s success was that the politicians at all levels and parties were united in their arguments and goals. It was a significant victory for Stavanger, particularly given that both Bergen and Trondheim had stronger academic communities. Bergen was known for being the home of the Norwegian School of Economics and Business Administration, the University offered education in geophysics, and also accommodated the Ocean Research Institute. Trondheim was proud of its technology-oriented university.

The Parliament committee chair Thorbjørn Berntsen proposed Stavanger to the parliament with the following arguments: *"As a new oil nation we need to learn and acquire experience. That knowledge is best facilitated where the oil activities progress in living life. Much nice can be said about Bergen and its University and about Trondheim and its technical university. But these cities have a serious drawback: no oil has been proven there. We cannot let the state owned oil company start with a handicap in being localized at a comforting distance to where the oil activities are or will be for many years to come. If we do, we will make both ourselves and the company a great disservice."*

Stavanger achieved 75 votes, Bergen 20 and Trondheim 49. Stavanger was on its way to becoming the oil capital of Norway.

It was not all smooth sailing. New pressures arose in the local labor and housing markets in the 1970s, as the oil industry was able to pay much higher prices. Traditional industries lost valuable talent, and had to pay higher rents. The traditional shipyard Rosenberg, which had been Stavanger's pride for decades, educated welders only to see them leave for better paid jobs in the oil industry. The debate on overheated and pressured markets soon reached the Norwegian parliament.

An interim "Act of Establishment Control" was introduced in December 1973 to control new establishments in certain locations so as to avoid further worsening of market pressures, and the Act was made permanent in January 1977. The Ministry of Local Government was worried about the rapid expansion in the Stavanger region. In the two-year period between 1976 and 1978 the Stavanger region's share of oil related jobs rose from 30% to 50%. A working group from several ministries concluded in 1978 that:

- No new oil companies to be established in Norway can be localized in Stavanger
- Established oil companies cannot make substantial expansions in the Stavanger area

The mayor of Stavanger was furious at what he regarded as state meddling in local matters from afar. The regional newspaper interviewed the mayor of Aberdeen (it is interesting to note that Aberdeen was even then considered a competitor) who proclaimed: "*In order to gain control of the oil business it is important to have all oil companies localized at one site and provide them with satisfactory development opportunities there… Efforts to stifle ongoing activities will harm all involved. We are fighting in such tough environments that we have to support successes whenever one comes our way"*.

The final regulation was less strict than the original version. While the Act recommended that all new oil companies be established outside Stavanger, it allowed established companies to expand according to their needs and strategies. The mayor concluded that as long as the present companies could expand, the region would still prosper.

In accordance with the law, Statoil was instructed to establish activities and operate them from other bases along the coast. The new rules were introduced from the fourth concession round (in 1979) where the applicants had to present an account of where the new activities would be located and how many people they planned to employ. Localization plans for a possible production phase also had to be described. If the company did not provide this information, the Ministry of Oil and Energy was authorized to direct the activities. Within a few years of the oil price shocks of 1979, with oil prices soaring above $30, oil bases were prospering along the coast, at Bergen, Florø, Kristiansund, Trondheim and Harstad. The Stavanger region's share of the oil business declined from 50% to 43-44% in 1981. After 1988 it re-established itself at around 50%.

8.1.2. Establishing the oil capital: Aberdeen

When the first North Sea oil discoveries were made, Aberdeen seemed no more likely to emerge as the center of the UK industry than did Stavanger in Norway. The main exploration sites on the UKCS during the 1960s were in the South, and Great Yarmouth played an important role in servicing their needs. It was not until 1969, when Ekofisk was discovered, that the potential for East Scotland became a reality (MacKay and Moir 1983). Even then, other established centers with decent harbors such as Edinburgh or Dundee were more serious candidates initially, and indeed the first oil companies landed in these cities in the late 1960s. There are differing accounts of when Aberdeen emerged as the unambiguous service centre for the oil industry. It certainly had not in 1970, but it certainly had by 1980 – later than in Stavanger.

Several factors appeared to influence the emergence of Aberdeen as a major oil center. First, local and regional authorities made concerted efforts to accommodate the oil companies. They were responsive to oil related planning applications; they took swift actions to provide much-needed industrial space; the Aberdeen Harbour Authority moved quickly in the early 1970s to make major modifications to its harbor so that it was as good in access as Dundee; the Airport Authority expanded its premises in the early 1970s. All of these were good reasons why Aberdeen was attractive to oil companies. A good example of the responsiveness of local and regional authorities was the clearing up of an old fishing village near the harbor to create space for Shell to establish its servicing base (Moir 1983). This action was coordinated with the North East of Scotland Development Authority (NESDA), which was active in promoting Aberdeen in the UK and US.

Second, the very fact that Aberdeen had a negligible manufacturing sector related to oil was attractive to American oil companies. Shipyards in the North East, for instance, represented very strong traditions of labor unions, which did not go down well with market-oriented ethos of American oil interests.

Third, once a few American operators set up their bases in Aberdeen for exploration, the dynamics of agglomeration set in. However, most operators established their UK HQ presence in and around London, where the key negotiations with the government took place.

In contrast to the Norwegian government's policies concerning Stavanger, the UK government's localization decisions worked against Aberdeen. The economic regeneration of Clydeside, the heavily industrialized area around Glasgow, was a policy priority in those days. Clydeside was seen as "the heart of the Scottish economic problem" of heavy unemployment and industrial stagnation. This was why the Offshore Supplies Office was located in Glasgow in 1974 (though it was moved to Aberdeen much later). Similarly, the headquarters of BNOC was located in Glasgow in 1975 – though this too was short-lived.

One economist, in reviewing these decisions, commented that "by any other yardstick they appear bizarre locations" (MacKay 1975). He speculated that "a strong case could be made for following a quite different policy – for concentrating the government offices associated with North Sea oil developments in the locations which are the centre for the activities of the private companies. In this way, one might better build up a centre of offshore technology with significant external economies." Nonetheless, he defended the government location decisions by saying that "the pressures operating in the other direction are real enough and in any event the precise location of government offices is often much less important than is supposed."

There were other decisions that were less explicitly locationally driven, but nonetheless had locational consequences, particularly in the capacity building for education and research. For instance, the two research capacities built with government funding were reservoir engineering in Winfrith and safety and technical integrity issues as in MATSU in Harwell – both in the South of England. Universities receiving support for petroleum engineering related funding were all over the UK – from Southampton to London to Strathclyde. Heriot-Watt was the only university to receive significant funding which was also reasonably close to the North Sea activities. As explained in the earlier section on education institutions, the Petroleum Industry Training Board established several training centers in Scotland – but none in Aberdeen (BB 1976). It was not until 1987 that Aberdeen Technical College was commissioned to have a ballast control simulator for training. Around the same time, a new drilling facility similar to Ullrigg in Stavanger was established in Aberdeen, but with no institutional connection to universities or colleges (BB 1989). Some would argue that there was little consideration given to regional policy in the UK – except to protect Clydeside (Cumbers 2000b).

As described in section 5, the focus of local government policies did not shift from enticing foreign companies to come to Aberdeen to promoting innovation until well into the 1980s. The policy emphasis on innovation was exclusively placed on corporate entities and did not entail significant investment in research or education capabilities within Aberdeen – at least partly because local and regional governments had limited ability to work with universities. This is perhaps the most significant difference between the two sets of regional authorities. Stavanger authorities took early actions to build education and research institutions within the region, as a natural extension of their localization measures. In Aberdeen, perhaps because one university and one polytechnic already existed, no specific action was taken to create new capacity.

Upgrading/deepening - Norwegianization vs. full and fair opportunity.

Once key external entities were attracted to the regions, how then did local capabilities develop? This section shows the different extent to which existing industries in the two countries were able to exploit opportunities to diversify into the oil and gas industry by broadening and deepening their expertise.

8.2.1. Norwegianization

In Norway, there was a clear understanding from the outset that the oil and gas resources belonged to the nation as a whole, and that they should be managed for the benefit of present and future generations. Though the Norwegian government initially relied upon well-established foreign companies to carry out all petroleum activities on the NCS, the government moved quickly to adopt explicit Norwegianization policies.

The first step was to establish government-owned operators. Under prime minister Per Borten, the government in 1970 bought shares in Norsk Hydro, securing a majority ownership of 51% (up from 47%). This Norwegian industrial giant had entered into an exchange contract with the Phillips Group in 1967, securing a 20% share of that group's exploration blocks and vice versa. Norsk Hydro's traditional businesses had been the production of electrical power, chemical products such as fertilizers, plastics and oil, and light metals including aluminum and magnesium. The company's motive for participation in the North Sea was to secure domestic raw materials and energy for its production of ammonia and methanol at Herøya (Eastern Norway). This arrangement proved to be a gold strike when Ekofisk was discovered. Norsk Hydro came to hold a 6.7% share of the giant oilfield, and in 1970 the company established an oil division. It was through Ekofisk that Norsk Hydro developed its capability in the oil and gas industry.

The successful experience of Norsk Hydro led to further actions by the Norwegians. The government established a wholly state-owned company, Statoil, in 1972, and a private Norwegian oil company, Saga, also emerged. Statoil was 100% state owned until 2001, and took a 50% interest in all production licenses awarded after 1972 until 1993. The process of privatization started in 2001 and currently the state holds a 70.9% share of Statoil. Norway also implemented the European Union's Hydrocarbon Licensing Directive and limited the average State share to around 39% in the acreage awarded. In recent licensing awards there has been a further decline in state participation.

In addition to the two state-majority owned oil companies, Statoil and Norsk Hydro, the largest player in economic terms on the Norwegian shelf is Petoro, a 100% state-owned company. Petoro handles the state's direct financial involvement in oil and gas activities in Norway (see the Appendix for more details).

When the first licenses were granted in 1965, Norway did not possess much negotiating power vis-à-vis the oil companies. However, in the early 1970s, as the large international oil companies were excluded from many of the petroleum regions in the world, oil prices began their rise, and Norway proved more and more promising as a petroleum region, the negotiating power of the Norwegian government increased tremendously, and it continued to do so throughout the 1970s and early 1980s. The concessionary procedure was used as an instrument to force the international companies to engage in technology transfer and local content development. For instance, Shell was asked to open its corporate university to Norwegians from Statoil, NPD or Hydro from the early 1970s, which helped to build valuable expertise among Norwegians.

In the initial projects for developing the oil fields, Norwegian companies were mostly absent. Most of these large projects were managed from offices abroad, tending to rely on suppliers with whom they had longstanding relationships. Norwegian firms did not possess the required capabilities even to tender. The development concepts and the business models effectively blocked participation for the Norwegian firms. In those days, Phillips usually awarded two contracts for each platform: one for design and engineering; and the other for fabrication, transport and installation at the field. In design and engineering, key integration capabilities were required, a competence that Norwegian firms did not command. For instance, the platform jacket designer had to know the layout and weights of all the various pieces that go on the platform before he could make an acceptable design (Nerheim, 1996). The other fabrication/integration contract was no less demanding: “This makes him responsible for scheduling; it makes him responsible for having cargo barges at the fabrication yard at the proper time; it makes him responsible for scheduling his derrick barge at Ekofisk to rendezvous with cargo barges” (Nerheim, op cit.). With full order books in the shipping industry, the engineering industry and the shipyards had little incentive to transform their business to exploit the new offshore opportunities. All contracts offered from the Ekofisk Group from 1970-72 were awarded to foreign companies, especially the American firms Brown & Root, McDermott and Santa Fe.

Even though the Norwegian government introduced a requirement in 1972 that Norwegian companies should be given a preference when they were competitive, there was initially little reason for the Norwegian authorities to enforce it, given the lack of capabilities or interest. This is not to say that there were no efforts made to build local capabilities. The spectacular Ekofisk tank was contracted domestically, and was a case in which Norwegian construction expertise in the use of concrete proved to have significance in local capability building.

Starting with the development of Statfjord in the mid 70’s, a model for Norwegian participation evolved. Since the early 70’s, the Norwegians had noted the importance of consulting engineers. Consulting engineers worked for operators to establish key development concepts[45], as well as specifications on equipment, the scale of construction, which firms to include on bidders lists, and so on. Norwegian consulting engineers possessed the capabilities required for these tasks, but they were generally too small to

[45] models and concepts on how to explore and exploit the oil fields

compete. Differences in work ethic also prevailed. Independence was in the backbone of Norwegian consultants, whereas foreign consulting engineers often worked for large corporations like Brown & Root and McDermott, which also built what the engineers designed. In 1975, ten Norwegian firms, among them Kværner and Aker, established a joint venture called Norwegian Petroleum Consultants (NPC) so as to be able to compete against foreign competitors in terms of the breadth and size of their capabilities. This is one example of efforts undertaken in order to develop local capabilities which required extensive collaboration across firms.

Mobil, as the operator of Statfjord, was willing to "Norwegianize" engineering capabilities. Nonetheless, it demanded that NPC, without a significant track record, should work in partnership with an experienced foreign company, in this case Brown & Root. Statoil preferred Bechtel but gave in to Mobil and the other partners in the license. Rapid knowledge transfer from Brown & Root to NPC took place; NPC consultants were invited to work with B & R on the Statfjord A project, and some of them worked physically at B & R's offices in London on the Statfjord B platform. Engineering specifications were made so that work was divided into smaller packages, better aligned to the size of Norwegian companies. As a result, the Norwegian content rose to 80% on the Statfjord B project. Statoil posited: "The geographical proximity and organizational contact established between the operator, the main consultant (NPC) and the executing entrepreneurs will result in better monitoring and control of the Statfjord B construction." NPC was awarded a similar contract related to Statfjord C and Gullfaks, this time in partnership with Foster Wheeler and Bechtel, respectively. Statoil was operator at Gullfaks, and could finally select its preferred partner. Since the consultants were employed by their respective firms, their employers took part in the capability diffusion. The concrete production platforms (Condeeps) were built in Stavanger in combination with topsides (steel deck and processing modules, and the hook-up) from Norwegian yards. Statoil recruited key personnel from the international oil majors to build sufficient internal knowledge and capabilities.

Aker pioneered platform designs and was awarded many contracts to design and construct platforms on the NCS as well as abroad. Its monopoly was broken when Kværner was awarded the prestigious Statfjord B construction contract. The global oil companies accepted the political expectations of comprehensive Norwegian deliveries, but only on competitive terms. The Kværner yard in Stavanger needed to document the necessary quality requirements. Welders completed courses in pipeline welding to satisfy the requirements from the American Society of Mechanical Engineers. With the award of the Statfjord C contract, the Kværner yard in Stavanger effectively became the main offshore yard for the Kværner corporation.

By the beginning of the 80's, the offshore industry had become the engine of growth for Norway. With very specific steps taken under the Norwegianization policies, local construction and shipping companies managed to diversify into the oil and gas industry, which was a significant achievement given the conservative and closed nature of that industry

A parallel development was taking place in pipeline laying capabilities. In obtaining the license for the Statfjord field, Mobil had agreed to hand over “specific jobs or carrying out defined studies to Statoil”. Realizing the economic and political importance of control and ownership of pipelines, Statoil proposed to Mobil that Statoil should take responsibility for planning and engineering the pipelines. This agreement gave Statoil a golden opportunity to develop competitive capabilities for laying pipelines in deep waters. In the years to follow, Statoil became the driving force for laying the pipelines, which represented huge investments. From the outset, there was strong political pressure on the industry to land oil and gas onshore in Norway. However, in the early years, it was technically infeasible to do so. But once the Norwegian trench was crossed, gas could be landed at several locations in Norway, including a location just north of Stavanger, leading to the development of petrochemical plants. In the 2000s, gas was also transported to Stavanger for use by other industries in the region.

Gradually, the mechanical engineering industry in the region joined the circus. Firms diversified out of agriculture and other sectors into the promising and emerging oil industry. This process became more pronounced when the young industry entered the construction phase. Norwegian construction entrepreneurs and the traditional shipyards became strongly involved in building the concrete platforms and their topsides. As the huge concrete platforms evolved to the “standard Norwegian model,” proximity again became the key. The fiords around Stavanger proved to be excellent locations for the construction work and their topside couplings. While outsourcing and subcontracting attracted the oil companies’ traditional partners to Norway in the initial phase, Norwegian companies began to join the industry in the production phase.

8.2.2. UK: ”Full and fair opportunity”

In the UK in the 1960s, there was very little understanding as to the potential size or impact of the North Sea oil discoveries on the economy. The government had very little expertise in oil and gas exploration and it had no option but to rely upon international companies’ expertise. The government (and public) expectation about the North Sea subsequently changed, particularly after the discovery of large fields such as Fortes in 1970 and with the rapid increase in oil prices during the 1970s.

In the 1970s and 1980s, the overriding preoccupation of the UK government was with severe macroeconomic imbalances, including large balance of payment deficits and high unemployment. The prospect of a new industry and of the inflow of foreign investment in the face of economic stagnation was very welcome. The result was a strategy of rapid depletion. Even though concerns were raised about ‘Dutch disease’ (whereby an inflated exchange rate from oil exports or reduced oil imports could lead to general decline in the competitiveness of other exporting sectors) and the adverse effects on other manufacturing sectors (through higher wages), except for a brief period in the mid-1970s, when the fears about escalating unemployment led to slower and smaller licensing rounds, the general pace of depletion has been rapid compared with Norway.

During the early period of North Sea development, the short-term need for rapid production took precedence over the long-term need to develop a domestic oil industry. The pressure to produce meant that it was essential to rely upon the technical and financial capacity of existing international oil businesses. Indeed, the need to build national capacity in the oil industry appeared only as an afterthought, prompted by a consultant report (commonly known as IMEG report) in 1972 which was highly critical of government policy. The report showed that British companies were not benefiting from the huge investment projects in the North Sea, and concluded that in most activities foreign contractors had a head start and their lead was growing (Cook et al 1982). Unless something was done, the British share of procurement would remain at a low (25%) level, and that the time to act was "now or not at all." As most of IMEG's recommendations were interventionist and at odds with the policy of the Conservative government of the day, the only one that was subsequently taken up was the establishment of the Offshore Supplies Office (OSO) to ensure that "full and fair opportunity" was given to British industry in procurement – and specifically to achieve 70% domestic content, as advocated by IMEG's report.

OSO was created in response to the report, with a mandate to ensure full and fair opportunity for British firms. OSO oversaw procurement activities by oil companies, based on a Memorandum of Understanding in which the oil companies agreed to the principle of full and fair opportunity. OSO monitored oil companies' placing of orders; it identified appropriate British companies and encouraged them to participate in bids; and it monitored performance of contracts. (The Conservative government had by then been replaced by a Labor government, which took a more interventionist stance; the new Minister of Energy, Tony Benn, wrote a letter to the board chairmen of the operators on the UKCS with a clear cut message: Buy British in 1975 (Nerheim, 1996).) OSO also played an intermediary role in bringing parties together to forge consortia and in helping with industrial reorganization. OSO played an important role in the birth of British Underwater Engineering, at the time of Vickers's withdrawal from subsea engineering. The OSO's link with DOE's licensing policies made this an effective body, and the 70% domestic share in contracts was achieved by the mid 1980s. The British Government also introduced interest subsidies to its offshore industry in 1973. OSO's interventionist function was phased out in 1992 as the single market program of the EU took effect.

The overall effectiveness of OSO, however, has been questioned (Cook et al 1982, Cameron 1986). While there was no doubt in the mind of operators that this was about 'buying British,' OSO did not distinguish between local firms and subsidiaries of foreign firm – indeed, foreign direct investments were welcomed given the short-term needs of the country for foreign investment and job creation. OSO policies also did very little to strengthen British performance in key technological areas where American companies had a considerable lead in technological know-how. Its objective had to do with increasing <u>any</u> domestic share, rather than targeting technological capacity building. Interestingly, a more focused approach was introduced much later, in the mid-1980s – but this came much too late to influence the industrial formation.

The establishment and the subsequent abolishment of a government owned company, the British National Oil Corporation (BNOC), reflects the rapidly changing policy priorities of the UK government during the period. BNOC was established as a state-owned oil company and producer by the Labor Government in 1976. Its role was to obtain a 51% share in fields already under development, to bring up the UK share from 25%. It was also seen as a means of encouraging the participation of UK's supply capacity – as in the case of Statoil. However, BNOC had a short life, as the new Conservative government announced its intention to dismantle it in 1979. In 1982 BNOC's assets were transferred to BRITOIL, a new private company, which in turn was sold to private companies.

For Aberdeen, the local capacity in the oil industry had to be developed from scratch. The Wood Group, a major international engineering company, today stands as virtually the only local company which grew into a global oil industry player, having begun as a fishing and ship repairing company. In the second tier are firms such as Balmoral and Abbot, but they are much smaller and have not yet established themselves as global companies.

The rapid development of the oil industry in Aberdeen also incurred transformation costs – in making some local industries uncompetitive because of escalating labor and other input costs in the region. In an essay that compiled the problems and opportunities of offshore oil for local industry, Ian Wood, the CEO of the Wood Group, wrote about how the traditional arms of his company in fishing and ship repairing suffered from the escalation of labor costs and the loss of skilled labor to the oil industry (Wood 1983). A report commissioned by the Aberdeen City Council confirmed that this was a phenomenon experienced by traditional manufacturing industries such as paper, fish processing and textiles in Aberdeen (McDowall et al 1983). The inability of local industry to adapt was exacerbated by the national 'incomes policy' in effect at the time, which restricted incumbent firms from adjusting wages upwards (MacKay 1975, MacKay and Moir 1983).

For the rest of the UK, shipbuilding, construction, and electrical engineering were the most obvious candidates to benefit from the new demands of the oil industry. The overall assessment is that such linkages did not develop by and large, either because the oil industry arose too late to save them or because the oil industry was not taken seriously enough at an early stage. The only exception in this category is AMEC, which was a large construction company, which developed to become a major global corporation – albeit diversified well beyond the oil industry.

The lack of local industrial capacity coupled with rapid depletion meant that US firms quickly became dominant in core technology-driven areas in the offshore supplies industry such as exploration drilling. The UK companies were largely confined to peripheral activities such as simple construction and servicing of fields (Cook et al 1983). British companies active in such areas early on included engineering companies such as John Brown and Matthew Hall (later absorbed by AMEC), both of which developed expertise in oil platform construction. Big technology-oriented manufacturing firms such as GEC, Ferranti, Plessey, and Rolls Royce played important roles in supplying specialized telecommunication or other equipment in the 1980s (Cook 1987), but have disappeared from the scene since then. The consequence was that British companies never won a significant foothold in the oil industry in key ‘core’ and technology-driven areas, and had to develop in the broader periphery – as in the case of the Wood Group or AMEC.

When the UK domestic capacity building policies are compared with the Norwegianization policies, it is clear that the Norwegians were more consistent and focused in this area. Norwegian involvement was either included in the license conditions or channeled through the state’s oil company, Statoil. As license owner, Statoil had access to information and good opportunities to influence decisions far more efficiently than the ministries.

The main consequences in the UK of fast depletion coupled with the lack of focus on the development of domestic capabilities were two-fold. First, international – most notably American – oil related companies flooded into the UK, often through joint ventures and establishment of local companies, helping to build domestic oil industry capacity. Second, local companies only entered the industry at the periphery, with the key areas (those requiring offshore specific facilities and know-how, such as exploration drilling, heavy lift installation work and pipe laying) remaining firmly in the hands of American companies (Cook et al 1983, Cameron 1986).

The dominance of the American companies did not mean that no local capabilities developed. Most of these companies recruited locally and nationally within Britain, and contributed to the development of experienced British personnel within the industry. The tendency to depend on local personnel became especially pronounced after 1986, when oil prices plummeted and many oil related companies had to send Americans home to reduce costs. Since then, the oil and gas industry in Aberdeen has experienced ‘boom and bust’ cycles which have led to constant mobility of personnel from one company to another. Many observers note that Aberdeen is characterized by small, specialized and innovative companies which were started by people who gained oil-related expertise through their career in international oil companies. It is as though international oil companies functioned as a mechanism to bring in a constant supply of experienced human resources, through their recruitment, rotations, and ultimately through firings. Some of these rich human resources became stuck in Aberdeen – creating a new kind of local capability.

Underlying mechanisms for internationalization, diversification and delocalization

How do local capabilities develop to become internationally competitive or diversify into new fields? When do existing capabilities become delocalized and depart from the region?

We attempt to address such questions by examining four categories of companies whose collective future seems likely to have a major bearing on the economic fate of the two regions. These are: global foreign companies, globalizing local companies, global domestic (but non-local) companies; and local small companies. We take these four categories as representing different vehicles or mechanisms through which local capabilities can evolve.

The main purpose of this section is to explore current developments in each of these four categories of firms, so to identify the conditions under which successful internationalization or diversification or successful avoidance of delocalization might occur. The discussion is necessarily speculative, both because our own research on these topics is preliminary, and because the underlying processes themselves are still at a relatively early stage. Our purpose here is mainly to outline future research that could shed more light on these issues.

8.3.1. Global foreign companies

Global foreign companies are an interesting vehicle for the future of local capabilities, because they can either be the most effective mechanism for internationalization, or be the most devastating examples of delocalization when they depart. In Aberdeen, some oil operators are beginning to show signs of moving on to other oil provinces. BP has sold its flagship field to Apache and has substantially shrunk its technological presence in Aberdeen. Shell has reduced its workforce in Aberdeen significantly and some other operators are leaving. As oil fields have been depleted, or companies not been granted new licenses, some oil companies have also decreased their staff in Stavanger. Departures of companies do not necessarily mean that all local capabilities are lost. Project team members are hired by new operators and stay where they are, while companies come and go. Departures of large operators are often compensated by arrivals of small independent operators such as Talisman or Apache. The question is what will happen as production in the North Sea declines if foreign operators leave.

One possibility is that foreign companies which have built unique capabilities in these localities may have greater propensities to stay than those that have not. The most important examples are the four integrated service providers, all of which have developed significant capabilities through acquisitions of small local companies.

Schlumberger acquired GECO, a company known for its innovative approaches in seismic analysis in Stavanger. Similarly, Weatherford bought up Petroline in Aberdeen and other companies to consolidate its capabilities in tubular technology. Indeed, in Aberdeen, the common expectation has been that if a small company does well with an innovative product, there will soon be an acquisition. The question is what happens to local capabilities after they become part of global companies. In the case of GECO, the company has flourished and is now the world’s largest seismic company. It would seem that in this case local capabilities have been enhanced through the global company.

Whether that reflects the reality requires further analysis. Since GECO was bought up by Schlumberger, it has undergone several rounds of mergers – first in 1991, with Prakla-Seismos and then in 2000, with Western Atlas. The resulting company, WesternGeco, is a joint venture between Schlumberger (70%) and Baker Hughes (30%). Until recently, the activities of WesternGeco were managed at Schlumberger's Stavanger location. Today, WesternGeco is headquartered just outside London. The question is, to what extent is it local to Stavanger today?

The presence of Weatherford in Aberdeen is a parallel story. Weatherford strengthened its capabilities through various acquisitions, and its Aberdeen operations became sufficiently prominent to assume the HQ function for the North Sea.

More needs to be known about these integrated service companies. How do local capabilities in the regions in which they operate influence their locational decisions? And what happens to capabilities resident in local firms after they are acquired by non-local companies?

8.3.2. Globalizing local companies

Some of the local companies in both regions have managed to develop into global competitors. Smedvig, Prosafe, and the John Wood Group were all active in other sectors before the oil and gas industry arrived. They diversified into oil and gas and gradually built their capabilities to become global players – sometimes through acquisitions of other companies.

Smedvig, a shipping company with roots dating from 1915, entered into the oil and gas industry at the very outset. Sensing the possibility of a new industrial era, the company invested in the future oil base area. The owner and the president of the company worked closely with regional politicians. The company invested in an exploration company, NOCO, and in supply vessels as early as 1965. In 1973 further investment was made through the design, development and construction of the first Norwegian-flagged semi-submersible drilling unit. Fifteen years later Smedvig purchased a large operator of mobile drilling units, Dyvi Offshore. Smedvig was listed on the Oslo Stock Exchange in 1990, the same year that it increased its international presence by acquiring a tender rig company headquartered in Singapore. In the first half of the 90's Smedvig expanded its business to include mobile production solutions that capitalize on advances in floating production technology (FPSO's). In 1996 the company was listed on the NY Stock Exchange. Between 1995 and 1997 the company further broadened its range of business, acquiring six reservoir software and management companies to offer reservoir technology products and services. These services are organized in Smedvig Technologies, which merged with Multi-Fluid in 1999 to create Roxar, now one of the world's leading multiphase measurement companies. Its technology makes it possible to measure the composition of oil, gas and water in the stream of oil from subsea installations at a depth of 3000 meters. Smedvig is headquarted in Stavanger and has 3750 employees; approximately 50% employed outside of Norway.

The case of Smedvig provides an interesting contrast to the John Wood Group in Aberdeen, which started out as a local fishing company and has become a global company today with over 13,000 employers, with 2-3000 in the UK. The Wood Group started in the industry from simple service provision and later developed engineering capabilities, mainly through aggressive acquisition of American companies. Its global headquarters is still in Aberdeen, but the bulk of its technical capabilities appear to reside elsewhere.

Another contrasting case is that of Prosafe which has evolved into the world's leading owner and operator of semi-submersible accommodation and service rigs, a leading platform-drilling contractor in Norway, and a major owner and operator of floating production and storage vessels outside the North Sea. The company employs around 1500 persons, half of them employed abroad. The present company originated from the American drilling company Moran Brothers in the early seventies. At the end of the decade it was acquired by the Norwegian company Norcem and merged later with Aker to become Aker Drilling. In 1989 Aker raised NOK 1.2 billion to buy the extensive drilling business from the American company Transworld drilling and the German companies Deutag, Preussag and Wintershall. It was the largest deal of its kind led by a Norwegian company. Aker then took the name Transocean and was in 1990 listed on the Oslo Stock Exchange. Transocean merged with Ross Offshore and Wilrig in 1994 and 1995 respectively. The following merger with the American company Sonat Offshore represented a temporary watershed. The merger implied that all operations in Norway would be managed from the Houston headquarters. It soon emerged, however, that the Americans and Norwegians held different views on future strategies. A Norwegian group bought the drilling business and established Procon Offshore, which in 1998 merged with Safe Offshore, to become Prosafe. Soon after, the merger with Consafe Engineering Ltd. in Aberdeen and Discoverer ASA was a reality.

The complex corporate history of Prosafe is a feature of the oil and gas industry globally, but what is interesting here is how the local company appears to have managed to 'buy' foreign companies both locally and abroad to develop its capabilities.

Again, in any of these examples, it is not at all clear how and what local capabilities developed and what their future is likely to be. It will be important to explore the effect of local conditions on the growth of these local companies, and on the regeneration of local capabilities.

8.3.3. Global domestic companies

Local capabilities can also become part of domestic companies headquartered outside of the localities. The conglomerate Aker Kværner provides a good example. Its business areas include general engineering and construction as well as oil and gas. Its corporate development history is a complex one of successive mergers, acquisitions and divestitures. Today it has four companies headquartered in Stavanger, which are indicative of how local capabilities developed. Out of a total of 20,667 people employed by Aker Kværner by the end of 2004 (26,350 including hired agency personnel), 3000 are living and working in the Stavanger-region.[46] On the other hand, the locally-based companies also have operations elsewhere. The Stavanger-based Aker Kværner Offshore Partners, for example, employs people from all over Norway – either people working onshore at its branch offices or people commuting to offshore installations.

AMEC is a British counterpart to Aker Kvaener, in the sense of being a global non-local domestic company, at least partially involved in the oil and gas industry, though with much less obvious capabilities or presence in Aberdeen.

The question is what role the two localities have played in the development of these global domestic companies.

8.3.4. Local niche companies

Finally, both localities pride themselves on a solid group of small innovative companies. Some have grown into global players in their own right, while others have been bought up by larger companies. But still others remain independent, and their future development is likely to have important implications for their regions.

There are several interesting cases of small innovative companies in Stavanger which arose from local technical research capabilities. Roxar ASA in Stavanger is an independent technology services company employing approximately 500 people worldwide. It is recognised as an industry leader in 3D reservoir characterization and simulation software, permanent downhole sensors and direct multiphase flow meters. Its corporate headquarters are in Stavanger but it has overseas offices in cities including London and Houston. Roxar grew directly out of the R&D unit of Smedvig. A former employee of Roxar recalls that it took over 10 years before the company could make money on its 3D visualization software. In the meantime, its product development was supported by the Norwegian operators as well as by Exxon. During the development phase, it worked closely with the Norwegian Computing Centre (based in Oslo), which introduced stochastic modeling to the product, a critical element in enabling 3D visualization.

Hitec, another Stavanger-based company, is known for its early innovations in computer-controlled remote control drilling. The technology arose directly from joint industry projects undertaken by RF. Hitec was established before RF began to have an explicit focus on commercialization. Today, RF has a portfolio of 20 companies and expects to be spinning out 4-5 more companies a year based on its research capabilities.

The most visible start-ups in Aberdeen have had a somewhat different character, as confirmed by many of our interviewees. Their founders had typically worked in global oil related companies, gained significant operational experience internationally, and developed many of their ideas directly from such experience. Andergauge is one such example. The company is known for its innovation in adjustable stabilizers, which

[46] Information provided by the information office at Aker Kværner.

allowed drillers to continue drilling without having to take the drilling equipment out of the ground to make fine adjustments – a process that used to take 24 hours. The original idea was developed by its founder, based on his extensive international operational experience in drilling, gained while he was employed in several US companies, including Schlumberger and Santa Fe. Andergauge enjoyed a decade of monopoly with its adjustable stabilizers – a significant duration in any industry. The company is now on its second product, which is as successful as its first – and intends to remain a private independent company.

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. Geolink, a company which exports 95% of its specialized measurement device products, was started by five founding directors who left another global service company which was being bought up by Halliburton.

All the small innovative companies interviewed in Aberdeen focus on development rather than research. They cannot afford to do research themselves, but they also recognize the need to be linked to some research capacity – to avoid costly mistakes. Private research organizations are also expensive and – for some of these firms – beyond reach, and universities are potentially a lower-cost alternative source of research. However, most of the companies we interviewed were adamant that their experience with university people was mostly negative. Among the complaints: professors were too slow; universities were amateurish and greedy in handling intellectual property rights; they did not understand the company concerns, and so on. This was in spite of the educational ties they had with universities. One founder was a graduate of RGU, another had recruited diploma graduates and had sent them to RGU bachelors engineering courses to upgrade their knowledge. Another pointed out that small companies such as his could not hope to recruit nationally – and had to work with local graduates from the two universities.

In contrast to the steady generation of spin-off companies from RF in Stavanger, there is only one technology-based university spin-off in Aberdeen. Its technology is still at the prototype development stage. Its entry into the oil and industry was almost accidental in that the company's product was originally developed for water pipes, independent of the oil and gas industry.

The difficulties small companies have in working with universities is consistent with the findings of a recent government review of university-industry relationships in the UK, which concluded that universities find it particularly difficult to work with small companies, which have neither the time nor the money nor the capabilities to work with universities (Lambert 2003).

An unusual technology-based company that appears to have worked out its relationships with universities had a founder who had extensive R&D experience with British Aerospace. The company specializes in underwater measurement devices, and has won several awards for its innovations. The founder developed half a dozen relationships with universities involving PhDs at the scientific end of its R&D activities, while the company itself undertook the engineering aspects. He could not pay up for this work upfront, so he had worked out various arrangements in which he would share the profits with universities.

> '*DTI and Scottish Enterprise have all sorts of nonsensical programs but no structure for SME to work with universities! So I had to create my own method*.'

In contrast to Stavanger, many observers in Aberdeen pointed out that the environment for small innovative companies has worsened considerably. The industry norm of EPCIcontracts has eliminated opportunities for these small companies to work with their ultimate users, the operators. Small innovative companies now find themselves in an uneasy relationship with contractors or integrated service providers: any innovation they come up with could be competing directly with the approaches used by these large global companies (Crabtree et al 1997).

These anecdotal observations suggest that small innovative companies in the two regions may be operating in very different environments. There are at least three possible differences that deserve further study.

First, the level of research capabilities associated with the companies may be different. Aberdeen's innovative companies appear to be driven directly by vast operational experience gained through exposure to international industry. In contrast, Stavanger's innovative companies appear to have emerged from some applied research capacity locally.

Second, there appear to be underlying differences in the career patterns of people in the two locations. In Norway, the oil and gas industry has had a high profile and has never had problems in attracting the best and the brightest university graduates from many disciplines, both at the bachelors and the masters level. These Norwegian graduates from joined the industry and often developed careers working with Norwegian and foreign companies, as well as government and research institutions. In contrast, the UK oil and gas industry depended on the reputation and ability of global companies to draw in talent, again in a diverse set of disciplines. The British recruits (many without bachelors degrees) joined the international circuit in the global oil and gas industry including the North Sea, and gained extensive operational experience often by moving from one company to another. This diverse pool of talent has been a key source of entrepreneurship in Aberdeen.

Third, there may be differences in the level of inter-firm collaboration between the two locations. In Stavanger, Statoil as well as other operators such as ConocoPhillips play a proactive role in developing and sponsoring new technologies, often in collaboration with others. An integrated service provider in Aberdeen explained that most new independent oil companies were conservative technologically, but that Apache was a rare exception in its willingness to move very quickly and aggressively with new technological ideas. He went on to remark that in Norway, 'the whole country is an Apache!', in the sense that there is a strong culture of trying new technologies, supported solidly by operators such as Statoil, Norsk Hydro and ConocoPhillips. Inter-firm collaboration appears to be alive and well in Stavanger. In contrast, in Aberdeen, small companies with innovative ideas are increasingly isolated from their users, as a result of cost cutting initiatives that have led to streamlined contracting. One group of researchers found that ‘inter-firm trust was at a low level, and that this was a barrier to firms’ willingness to give their best in an alliance.’ For small innovative firms, not only did contractors become a barrier to communication with end users, but they could also be the first to appropriate the innovations. The fear that others might appropriate their technology was most keenly felt by small technologically innovative firms (Crabtree et al 1997).

Concluding remarks: Industrial development processes

Both countries confronted the problem that they had virtually no local capabilities in oil and gas extraction at the outset. The UK was perhaps at an advantage, given the very considerable experience of BP and Shell. However, even with British government holding a small share in BP, it had little leverage over the company – BP was already an international company heeding its own business. Besides, the extraction and production of oil requires a whole range of supply industry functions – none of which existed in the UK or Norway at the time. 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 different in two ways. First, localization processes within each country were different. It was not at all obvious that either Stavanger or Aberdeen would become major centers for oil and gas at the outset, as there were many contenders. Local authorities in both Stavanger and Aberdeen worked hard to attract key industrial players into their regions. However, there was a significant difference in the level of agglomeration achieved by the two localities. Stavanger went further and was also fortunate in getting key government organizations to locate there, and in developing educational and research capabilities directly linked to the industry. As a result, significant differences emerged not only in what was localized at the outset, but also in the way the transition was made to the upgrading/deepening phase of local capacity building.

Second, Norway adopted an explicit and consistent Norwegianization policy from the outset, in a way that was not matched by their British counterparts. It is not that the UK never took any domestic capacity-building measures – but its efforts started late, changed over time and did not go as far. In Norway, different local industries such as construction, shipbuilding, and mechanical industry were brought into the oil and gas industry. Stavanger became the platform for these domestic but non-local companies to launch into the oil and gas industry. In contrast, in the UK, none of the candidate industries such as construction, shipbuilding, or electrical equipment manufacturing made a grand entry into the industry. In both places, however, there were some exceptional local companies which did diversify into the industry.

These differences were further reinforced by a critical difference in the speed with which the industry was developed. The UK adopted a faster depletion policy than Norway, which meant that foreign companies moved into the oil business in the UKCS quickly, leaving little time for domestic capabilities to develop or catch up. This was mainly owing to macroeconomic conditions; at the time, Britain had massive balance of payments problems coupled with unemployment, whereas Norway had full employment and generally healthy macroeconomic conditions. As one analyst commented:

> *'It seems that macro-economic considerations have been decisive in both countries, in particular with regard to depletion policy…it has been rational for the UK to opt for a high rate of extraction and equally rational for Norway to opt for a low rate of extraction.*' (Noreng 1980).

The UK introduced specific measures to develop domestic industry capabilities slightly later than Norway. However, given the speed with which American industry was coming into the UK, the delay of a couple of years meant a significant difference in the impact these measures could have on the ground.

The net result of these differences was that British industries that might have diversified into the oil and gas industry such as shipbuilding did not do so, while in Norway, both the shipbuilding and construction industry managed to grow through the new markets in the North Sea. The Norwegian government intervened specifically and vigorously to ensure that the oil industry opened doors for them. The industrial transformation that Stavanger went through entailed diversification of existing local industry as well as the arrival of foreign companies, while in Aberdeen, the dominant process was the arrival of foreign companies.

By examining various capability-building processes, we have gained insight into the differences in the innovation systems in the two localities. In Stavanger, Statoil has long played a critical role both as a sponsor and a user of new technologies, contributing significantly to capacity building in local companies. Even with the changing contractual relationships such as EPCI and with decreasing state ownership of Statoil, there appears to have been no significant change in the role of Statoil as a technology and local industry champion.

The local innovation system appears to comprise not only operators and supplier companies of all sizes, but also RF, a public research institute with a significant capability in application-oriented research, and UiS, which gradually developed to acquire full university status. Particularly striking in Stavanger are the networks, both visible and invisible, and an underlying collaborative culture that developed around these organizations.

Present in Stavanger are organizations whose presence may be sustained even when the oil production in the North Sea declines: Statoil and Petoro, a growing number of regionally-based companies are going international, such as Smedvig, Prosafe, Technor, Sevan, and Scana. Some start-ups are going international directly (e.g. International Plugging Specialist). Engineering and consultancy firms like RC (Rogaland Consultants) and Sørco, and a comprehensive cluster of small niche technology producers are working to make the oil and gas cluster complete, which – according to theory and empirical evidence (Reve and Jacobsen, 2001) stimulates innovation. Demanding customers are in place, and a large number of differentiated suppliers compete for business and solutions.

In contrast, the essential element of Aberdeen's local capability appears to be rich and diverse human resources, which developed as a result of flexible labor markets and many foreign employers. Many UK nationals were recruited into the global oil and gas industry in and out of Aberdeen, gained significant operational experience both abroad and at home, and formed their own companies around ideas they developed through such experience. If there was a singularly important mechanism for innovation, it was that there was no job security, nor obvious career trajectories. Rather, a diverse group of individuals were exposed and tested by market forces – and so gradually built international competitiveness. What emerges from this story is that two distinct innovation systems were operating in Aberdeen and Stavanger, the former based on market mechanisms, and the latter with decisive elements of collaboration and coordination.

9. Discussion and conclusions

Stavanger and Aberdeen have clearly taken very different paths in 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.

Norwegian authorities at national, regional and local levels made concerted and consistent efforts to develop local capabilities in the oil and gas industry. Their strategies were specific and consistent, and included the creation of a national oil company, STATOIL, the use of specific licensing conditions to require foreign companies to assist in technology transfer, and the development of higher education and research capacities in key related fields. These strategies not only assisted existing local industries such as shipbuilding and construction to enter the oil and gas industry, but also helped emerging local companies to grow and become competitive internationally. Stavanger, as the uncontested oil capital of Norway, is the product of such efforts.

Aberdeen emerged as the operational center of the North Sea sector of the U.K. oil and gas industry, which – in contrast to the Norwegian industry – long predated the North Sea discoveries. Major UK firms such as BP and Shell had long been active internationally, and the administrative and financial center of the UK industry was in London. The industry in Aberdeen grew despite the lack of consistent support from the national or local authorities. This is not to say that no efforts were made to build local capabilities. It was the responsiveness of local authorities in the 1970s in providing key infrastructure that helped establish Aberdeen as the obvious site for the industry. The national government also made 'Buy British' a norm among foreign operators in the 1970s. However, the British localization policies lacked the specificity that their Norwegian counterparts had – no distinction was made between British companies and foreign subsidiaries. There was also no systematic effort to develop education or research capabilities. Institutions such as Heriot Watt emerged as a result of their own efforts - including efforts to obtain government support for their plans – rather than through planned approaches by the state at any level. Indeed, many of the domestic capacity-building efforts, particularly in research, were submerged amidst the massive waves of industrial restructuring and privatization. Perhaps it is fair to say that the industrial issues facing Britain in the 1970s and the 1980s were so enormous that policy makers had neither the time nor the inclination to be proactive in the oil and gas industry.

The result is that very different local innovation systems emerged in the two settings. Stavanger has managed to develop a local innovation system which is based upon implicit and explicit collaboration and coordination among key players including Statoil, local and national government, domestic and foreign companies, as well as education and research institutions. Statoil, which is itself the product of an earlier coordinated effort to build domestic capacity, today plays a critical leadership role in maintaining the tradition of industry-wide collaboration, particularly in introducing new technologies. Particularly striking in Stavanger are the networks, both visible and invisible, and an underlying collaborative culture that developed around these organizations.

In contrast, the essential part of Aberdeen's local capability appears to be rich and diverse human resources, which developed as a result of flexible labor markets and many foreign employers. Many UK nationals were recruited into the global oil and gas industry in and out of Aberdeen, gained significant operational experience both abroad and at home, and formed their own companies around ideas they developed through such experience. If there was a singularly important mechanism for innovation, it was that there was no job security, nor obvious career trajectories. Rather, a diverse group of individuals was exposed and tested by market forces – and so gradually built international competitiveness. What emerges from this story is that two distinct innovation systems have been operating in Aberdeen and Stavanger, the former based on market mechanisms, and the latter with decisive elements of collaboration and coordination.

These very different strategies do not appear to have led to significantly different levels of international competitiveness. Rather, the two regions are competitive in different ways. As we saw in Section 3, if Aberdeen appears to have some advantages in terms of operational costs, Stavanger shows its competitiveness in its ability to introduce new technologies. In the race to internationalize and export their expertise to other oil provinces, both localities appear similarly successful and have seen rapid increases in the level of exports in recent years, though Aberdeen leads both in overall export volume and in the diversity of its international markets. 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 three possible reasons for such findings. First, it may be that more time will need to elapse before the full effects of these differences become visible and measurable. Second, it is possible that our simple measures are inadequate for capturing differences that may already exist. A third possibility is that different innovation systems and practices may be associated with similar performance outcomes over a sustained period.

The lack of conclusive evidence in process outcomes clearly calls for further investigation and analysis, but the very fact that performance differences are not visible in this first cut analysis already tells us that there is no clear winner in this comparison. Aberdeen has been a robust player in the international setting in spite of the lack of strategic support from national and local governments that Stavanger has had. Aberdeen must have been able to draw on resources that Stavanger may not have had, in order to be able to retain its competitiveness at this level.

There are three possible candidates. One is the power of flexible labor markets in bringing an internationally experienced labor force to Aberdeen. Some of that human capital then became embedded in the locality, and helped to create innovative small businesses. These businesses have been competing in spite of a relatively inhospitable environment, which has been characterized by a lack of support from operators, financial institutions, or research institutions. Perhaps this environment has promoted a Darwinist winnowing out, in which the fittest have survived at the level of both companies and individuals.

Another possibility is that the strength of Aberdeen comes from its connectedness to the global centre of the oil and gas industry, Houston. As our patent analysis showed in section 7, today Aberdeen inventors are intricately connected to American companies, many of which are based in Houston. Such connections can be seen negatively, as a form of subjugation to foreign companies' interests, or positively, as a way of keeping up with the global industry. The fact is that some of these global companies have decided to use Aberdeen as their key sites for the Western Hemisphere, and are consolidating their presence, rather than leaving.

The third possibility is that there are new developments in Aberdeen associated with brownfields – developments that so far are not visible in Stavanger. The capabilities that developed in the North Sea in the 1970s and 1980s were influential globally because they pioneered deepwater exploration and production. Today there are many deepwater provinces around the world, and the North Sea is no longer unique in this respect. On the other hand, the North Sea is now pioneering the exploitation of deepwater brownfields. And as one of our interviewees stated simply, the future of the oil and gas industry will eventually have to do with dealing effectively with brownfields. In this regard, Aberdeen may still be providing opportunities that are distinct in relation to other oil provinces. And as new players – including new independent operators – arrive and bring new ways of doing business, so may local capabilities develop in new ways.

One other observation that emerges from our analysis is that neither locality appears to have developed strong industry linkages to science. Even with concerted government support at all levels, the real scientific capacity is still in the making in UiS, and the oil and gas industry still looks to other regions for its main scientific linkages. The linkages to industry at the University of Aberdeen have been based on individual efforts spread across a number of areas. There has been no concentration or focusing of expertise, and little visibility. Both regions may thus be neglecting one possible route to survival. Other locations which have managed to put themselves on the oil and gas industry map without having oil resources of their own have often done so on the basis of their research and scientific capabilities. Celle in Germany is a location where highly specialized expertise is making it attractive for a global integrated service provider to maintain its R&D activities. In the two Cambridges, in the UK and in Massachusetts, general scientific expertise rather than specialized capabilities is attracting an oil and gas industry presence. The question is whether either of these logics may have a role in Stavanger and Aberdeen in the future.

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11. APPENDIX

Key government institutions in the two countries

Norway

The government holds the executive power of the petroleum industry and is responsible to the parliament. In implementing policies, the government and the ministries are supported by directorates and agencies. The responsibilities for the various parts of the policies are distributed across ministries as follows:

- The Ministry of Petroleum and Energy: overall management of resources and sector
- The Ministry of Labor and Social Affairs: health, safety and the working environment
- The Ministry of Finance: state revenues and tax systems
- The Ministry of Fisheries and Coastal Affairs: oil spill contingency measures
- The Ministry of the Environment: the external environment

In order to ensure the interests of the society as a whole, the authorities seek to influence the companies' decisions through clear-cut and predetermined frameworks. This reflects the belief that this system is able to *align* the interests of the companies and the benefits for the society. Conflicts are resolved through a combination of market competition and a number of coordinating institutions and mechanisms in which the companies, industry associations and government take part.

The following institutions report to the Ministry of Petroleum and industry:

The Norwegian Petroleum Directorate (NPD) was set up to secure the optimal resource utilization on the NCS based on safety regulations and environmental policies. They keep up a total overview of the present and potential resources and command a unique and trustworthy information and knowledge base to provide transparent data for all players. When compiled and distributed in a coherent manner, it contributes to ensure that decentralized decisions by the operators may be taken at the appropriate time for the best results. The NPD may stimulate innovative activity through ambitious targets for the future development of the oil and gas industry. In their latest report (2005), the NPD sets a new target for additional recovery of oil, requiring new technologies for improved recovery and many new fields in production with a high level of exploration. Furthermore, the necessity of reduced unit costs is underlined, advocating integrated operations through so called e-production. They also stress the importance of knowledge transfer*: "Operating costs can be significantly reduced just by taking the best methods and equipment into use."* The NPD is located in Stavanger with the UiS and RF as closest neighbors.

The Petroleum Safety Authority Norway is monitoring the safety, contingency measures and working environment. The institution is located in Stavanger (co-located with the NPD) and reports to the Ministry of labor and social affairs.

Petoro AS is a state-owned corporation responsible for the State's Direct Financial Interest (SDFI) on behalf of the state. It is located in Stavanger. Through SDFI the state owns interests in a number of oil and gas fields, pipelines and onshore facilities. Its stake is determined when production licenses are awarded, and the share varies from field to field. The SDFI was established in 1985 as a result of a split of Statoil. When Statoil was listed and partly privatized in 2001, the administration of the SDFI was transferred from Statoil to Petoro. The SDFI institution means that the government, when awarding acreage, can decide the state's share of the expected value creation. Downstream Petoro collaborates with Statoil which is responsible for the combined sale of its own and the government's petroleum

Gassco AS is a state-owned corporation responsible for the transport of natural gas from the NCS. The company operates Gassled, the transport system for Norwegian gas, i.e. the pipelines and terminals. Gassled is owned by a partnership of oil companies present on the NCS, with Petoro (38%) and Statoil (20%) as major shareholders. Gassco is located in the Rogaland county.

Statoil ASA has been the main instrument in implementing the policies of the state. Established as a greenfield company in 1972, Statoil has developed into the major operator on the NCS, operating huge fields like Statfjord, Gullfaks, Sleipner, Snøhvit etc. Headquartered in Stavanger, Statoil has been an important player in the petroleum related innovation system through its determined strategy to exploit new technology. Though the history of the NCS, Statoil's share of total investments is 20%;(NOK320 bill.) of which 60% has been contracted with Norwegian suppliers. Since the mid 90's Statoil has made efforts to global. Today, it is present in 27 countries, and is operator or partner in ten. Statoil was listed on the Oslo and NY stock exchange. As of March 1 2005, the state own 70.9%. Statoil's present strategy is twofold: maximizing values from producing fields on the NCS through IOR technology and an aggressive exploration strategy. This means that Statoil will continue to operate and look for huge fields (as all majors do) combined with continued focus on tail end (late life) and small field production. Secondly, international ambitions are planned to increase non-NCS production to 40%. Statoil UK was established in 1982 in London and participates in more than 60 blocks in the UK North Sea and on Atlantic Margin. The subsidiary is also an operator on the UKCS, including the Atlantic Margin.

The State Petroleum Fund was established in 1990 to ensure the long term perspectives of the petroleum income, and to shield the Norwegian economy from fluctuations in oil prices and income streams. The fund has grown to become one of the major institutional investors in the world, as all investments are channelled abroad. The value of the fund amounted to NOK 1090 bill at the end of March 2005. The Ministry of Finance has delegated the operation of the fund to Norges Bank (The National Bank of Norway)..

Coordinating the industry

The industry is coordinated partly through ordinary market mechanisms, partly by government initiatives and institutions.

The Topplederforum (*Senior management forum)* was initiated in 2000, under the leadership of the Minister of Petroleum and Energy. The forum counts around 30 senior managers from oil companies, the supply industry, labor organizations and the authorities. Its ambition is improve the competitiveness of the NCS as well as the competitive strength of the Norwegian supply industry, both at home and abroad. Proposals include projects and working processes related to the cost level on the NCS as well as improved cooperation within the sector.

INTSOK – Norwegian Oil and Gas Partners – is a foundation established by the authorities in 1997 in partnership with the industry. With around 150 members, INTSOK supports and promotes Norwegian petroleum industry internationally. The goal is to increase the export of products and services.

Petrad, co-located with the NPD, offers training and knowledge transfer programs to the management of national oil companies and petroleum authorities in emerging economies.

UK

The main oil and gas related functions within the UK government can be described in terms of the following:
(a) Department of Energy (DOE) subsequently absorbed into Department of Trade and Industry (DTI);
(b) Offshore Supplies Office (OSO) – a unit within DOE/DTI explicitly charged with industry policy aspects;
(c) Licensing and Consents Unit, which includes two sections, one responsible for pollution and decommissioning (30 employees in Aberdeen, 4 in London), one responsible for licenses, exploration and development (20 employees in Aberdeen and 50 in London)[47]
(d) British National Oil Corporation (BNOC), a British national oil company

Department of Energy (DOE). DOE was responsible for general oversight of North Sea developments, and was the key body for making licensing decisions. However, their role in overseeing oil and gas industry was not clear cut- as DTI was also at least partially 'responsible' for industry development. The initial decision to place OSO within DTI, and subsequent decision to move it to DOE reflects such ambiguity. Nonetheless, DOE was the main government body responsible for all main aspects of the North Sea. It was DOE which produced annual oil related statistics and information in the form of the "Brown Book."

[47] RF Report 2003/229: Delingen av Oljedirektoratet (The split of NPD)

DOE was absorbed into DTI in 1992 and its licensing responsibility is now within DTI. There has been a general decline of government presence in this sector as the Brown Book was discontinued (as of 1999?) and as DTI continues to downsize (downsizing its oil and gas unit significantly in 2004). Except for OSO, all of its oil related units were located in London.

Offshore Supplies Office (OSO). OSO was created in response to a report published in 1972 which was highly critical of government policy (IMEG 1972). The report showed that British companies were not benefiting from huge investment projects in the North Sea, and concluded that in most activities, foreign contractors had a head start and their lead was growing (Cook et al 1982). Unless something was done, the British share of procurement would remain at a low (25%) level, and that the time to act was "now or not at all." As most of IMEG's recommendations were interventionist and at odds with the Conservative government, the only one they subsequently took up was the establishment of OSO to ensure that "full and fair opportunity" was given to British industry in procurement – and specifically to achieve 70% domestic content, as estimated by IMEG's report.

OSO's main function was to oversee procurement activities by oil companies, based on a Memorandum of Understanding, in which the oil companies agreed to the principle of full and fair opportunity for British firms. They monitored oil companies' placing of orders; they identified appropriate British companies and encouraged them to participate in bids; and they monitored performance of contracts. They also played some intermediary role in bringing parties together to forge consortia or in helping with industrial reorganization. OSO played an important role in the birth of British Underwater Engineering, at the time of Vickers withdrawal from subsea engineering. The OSO's link with DOE's licensing policies made this an effective body, and 70% domestic share was achieved by the mid 1980s. OSO's interventionist function was phased out in 1992 because of the European Union.

The overall assessment by Cook et al is nonetheless critical on two accounts. First, OSO did not distinguish between local firms and subsidiaries of foreign firm – indeed, they were not in a position to, given the short term need of the country for foreign investment and job creation. Second, they did very little to even out the British performance in key technological areas where American companies had considerable experience and technological know how. Their policy was to do with increasing any domestic share, rather than to target technological capacity building.

British National Oil Corporation (BNOC). BNOC was established as a state-owned oil company and producer by the Labor Government in 1976. Its role was to obtain 51% share in fields already underdevelopment, to bring up the UK share from 25%. It was also seen as a means of encouraging UK firms. BNOC had a short life, as the new Conservative Government announced to dismantle it in 1979. In 1982, BNOC's assets were transferred to BRITOIL, a new private company, which in turn was sold to private companies.

http://web.mit.edu/lis/