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Offshore Engineering, Consulting and Innovation

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Preface

Services in Innovation – Innovation in Services (SI4S)

Knowledge-intensive services suppliers, such as financial services, R&D, business management consultants, engineering consultants, transport services and so on, are important assets of the Norwegian economy. More than 12.000 firms and approximately 115.000 employees work in so-called knowledge intensive business services (KIBS) .

These industries, directly or indirectly, contribute in some way to the improvement of the technical or organisational competencies in those industries that purchase their services. However, there exist little literature on which role such knowledge-based services play in a national innovation system; questions like 'how – and to what extent – do these services stimulate innovation in other services?', 'how do relations between KIBS and the buyer differ from industry to industry?' etc., have until now remained unanswered.

The EU Commission research programme TSER (Targeted Socio-Economic Research) has financed several national studies on services and innovation, through a joint project called SI4S (Services In Innovation – Innovation In Services). STEP has in addition to being project co-ordinator for the SI4S project, performed several studies on services in innovation and innovation in services.

Abstract

In this report, the importance of engineering consulting services for innovation performance in the Norwegian offshore oil & gas industry is outlined. The results presented are based on a number of case studies of the interactive problem solving that takes place between these highly technology-focused knowledge intensive business services (T-KIBS) and their customers in the offshore industry, primarily the oil companies and larger manufacturing engineering companies.

The engineering consulting companies has a strong influence on the innovative capability of Norwegian petroleum actvities. The nature of consulting engineering services are highly focused on knowledge transfer and problem-solving, which means that this service in an extremely large extent represent the innovation force in the Norwegian petroleum complex. The intensive use of such services also indicates that the petroleum acitivities are more innovative than most other Norwegian industries.

These firms propel both technological and organisational innovations. We show that the interactive networking between oil companies and consulting firms in many ways represent an advanced mutual learning process (Lundvall ibid.), and that this way of co-operation have resulted in concrete technological developments and organisational changes. Development of the EPCI contracts, which implies that consulting engineering companies become in charge of a total entreprise (engineering, procurement, construction and installation) strongly underlines the knowledge complexity that such organisations hold.

This report suggests a theoretical framework within which the innovation process in Norwegian petroleum activities might be better understood, and it suggests how policy towards stimulating innovation in the industry could be shaped.

Keywords: Consulting; Engineering; Innovation; Innovation system; Knowledge infrastructure; Learning; Technology

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Offshore engineering, consulting and innovation

Introduction

"...the big oil companies are surrounded by hundreds of small enterprises and research institutes in networks with strong interconnections. This, together with the size and complexity of the [offshore oil industry] projects, gives a dynamic milieu with a solid basis for innovativeness."

The Norwegian Oil Industry Association.

The offshore oil & gas industry in the North Sea in Northern Europe is an economic area with a substantial degree of innovation activity. Examples of concepts which have been developed for the North Sea conditions through innovative engineering are the Aker H3 rig, the Doris concrete platform, the Submerged Turret Loading system (STL), document handling systems, workflow software, computer aided design tools (CAD), and new positioning systems[1].

There are two main reasons that explain these activities. Firstly, many new offshore technologies stem from the fact that the Norwegian shelf is considered a very difficult area to perform petroleum activities. The combination of big ocean depths and rough weather conditions (waves, ice, snow, winds) makes drilling and petroleum production more difficult in Norway than in other petroleum offshore areas of the world[2].

Secondly, Norwegian concession rules (e.g. on which conditions foreign oil companies may perform petroleum production on Norwegian continental shelves) have protected and propelled participation of Norwegian producers of services and goods to offshore activities. The technology agreements, stimulating foreign oil companies to perform R&D in Norway in exchange for petroleum production concessions shares, is one such arrangement. Co-operation with Norwegian suppliers in exchange for concession shares is another. These arrangements led to joint-ventures and co-operation and between oil companies and Norwegian suppliers, involving networks of technical and administrative staff integrated in one of the fastest interactive national learning- and innovation processes that Norway has ever experienced. New ways of doing things, new technology and new knowledge were gradually transferred from foreign actors to Norwegian supplier industries as a result of Governmental initiatives. This learning process can partly be illustrated by looking at employment figures. In 1973, 14% of the persons working in petroleum activities in Norway were foreign. Today (1996), the same figures are 4%.

As the petroleum activities involves innovative actions, a central part of the "nationalisation" of petroleum activities has been development of a national industry of consulting engineering. The role of this industry is primarily to help oil

[1] Braadland (1998)

[2] Braadland (1996)

companies solve problems by offering them technical skilled personnel in certain situations. These situations range from simple short-time problem-solving to long-term project development.

What these situations have in common, is that they are often related to development of a new petroleum production process or improvement of an existing petroleum technology system. In other words, the engineering consulting industry is at heart directly involved in innovation in other industries; primarily oil companies and larger manufacturing companies.

This paper bring a closer look upon the important dynamics of Norwegian engineering consulting industry and its role in the Norwegian petroleum-related innovation system. We want to highlight how innovation occur in consulting engineering, and we want to show of which importance the industry is for innovation in other industries.

Our point of departure is that innovative and successful business service companies are more thoroughly connected to their customers and suppliers than is usual for most manufacturing industries (Gallouj 1994). Change in competitiveness might thus just as much stem from customer's organisations or in the delivery system between the service provider (producer) and its suppliers. This has three major implications for our research;

1. We are looking for *systems* of innovation rather than exclusively firm behaviour, and thus we want to identify:
2. *interactive* processes of change rather than sequential realisations of good business ideas revisited post hoc by service producers (traditional 'case-stories').
3. We will focus on *sustainability* and the *generic* aspects of new products and processes that change so swiftly as opposing to the traditional focus on the creation of artefacts with rather clear cut price/performance and product cycles.

Chapter 2 contains a presentation of the size and structure of the Norwegian petroleum system, with particular emphasis on the engineering sector. Chapter 3 is a presentation of the internal and external dynamics of consulting engineering. Chapter 4 sums up the major conclusions, and outlines some policy issues.

Characteristics of the Norwegian offshore industry and engineering consulting services

Introduction

This chapter brings an overview of the Norwegian offshore oil & gas industry, with particular focus on the characteristics of the engineering consulting services.

Norwegian petroleum activities

As we have shown in Chapter 1, primarily a strong governmental involvment has secured the building up of a national offshore industry. This was done by attracting those firms (e.g. American companies) which held the appropriate knowledge to extract oil through prospects of large shorter term profits, in exchange of producer networks with Norwegian manufactures, suppliers etc.

The petroleum activities' role for consulting engineering in Norway can not be underjudged. The far most important single industry purchaser of consultant services in Norway is the offshore petroleum industry, and the North Sea (including Great Britain) represents the second largest market for offshore services in the world.[3] Today the Norwegian petroleum activities consists of 900 companies, it employs 70,100 persons (1995), which represent 3-4% of total employment in Norway.[4] The largest sub-sectors, measured in employment, are manufacturing (24,000), oil companies (18,000) and engineering companies (7,500). 9 % of the employment work in SMEs. The SMEs represent 50% of all firms in the sector. 81% of the employment work in large firms. The national average working in SMEs is 60% of the employment, 99,5% of the firms. Hence, the sector as a whole includes relatively few SMEs.[5]

In 1995, the offshore industry exported goods and services for approximately 12 billion NOK. The largest export fields were equipment/systems, engineering services, rig services and seismology. Export from small firms represents only 1,5% of total export.[6]

Some 250 million ECU are yearly spent on R&D within the industry. 80% of the funding is raised by the oil companies, 10% is public funded, and only 10% is spent by the total supplier industry, including offshore engineering consultants.[7]

R&D is usually performed within ongoing projects in co-operation with other participants. Thus the R&D is aimed at solving problems within specific projects and for customers; it is *client-led* and *project bound* [8]

Norwegian offshore engineering consulting (NOEC)

The birth of Norwegian offshore engineering consulting took place during the autumn 1975. A few entrepreneurial companies (Kongsberg Engineering, Aker and Kværner), the state owned oil company *Statoil* and some other individuals from ministries got together to establish the joint venture Norwegian Petroleum Consultants - NPC. In the beginning of the Norwegian petroleum era, large foreign engineering companies (like Brown & Root and Mattthew Hall) had taken on an important part of field developments. And it was not until 1978, based on traditional consulting engineering companies and engineering related to the

[3] *Global Oil Report* 1992.

[4] Source: Norwegian Directorate of Labour; Arbeidsdirektoratet, 1996.

[5] Source: Braadland, 1998.

[6] *Faktaheftet 96* from the Ministery of Business and Energy.

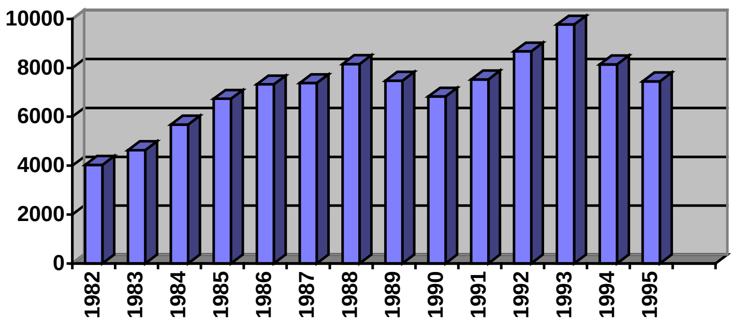
[7] Op.cit.

[8] Argued to be the case for KIBS in general by Bilderbeek and Hertog (1994).

Norwegian ship building industry, that NPC got its first major assignment. Under the leadership of Brown & Root NPC was assigned to participate in the development of the enormous *Statfjord B* project. At the end of this project more than half of the employees involved where Norwegian, and the share of Norwegians employed further increased during the construction of the *Statfjord C* platform, where NPC took on a leading role.

In 1980 the Norwegian offshore engineering consulting industry (NOECI) had captured some 2/3 of the North Sea market for engineering services. This increased to 90% during the second half of the eighties and has been kept on the same level since. At the beginning of the eighties the NOECI mainly consisted of three larger companies; Aker Engineering, Kværner Engineering and NPC. Also important where Kongsberg Engineering and EU Consultants. Norconsult came to be an important firm, with some 350 persons engaged in offshore related activities in 1984.

Figure 1: Norwegians employed in offshore engineering consulting 1982-95



(Source: Norwegian Directorate of Labour; Arbeidsdirektoratet, 1996)

The Norwegian offshore engineering consulting (NOEC)-services industry consists today of approximately 150 companies with some 7500 employees. Employees in NOEC constitutes 11-12% of total Norwegian employment in the national oil and gas industry. In general, business service firms in Norway are small. Two thirds have less than 5 employees and 85 % less than 10 employees. NOEC are somewhat bigger on average.

Engineering consulting services and innovation

Introduction

We can observe two major types of innovation resulting directly or indirectly from engineering consulting companies efforts; i) new technology (artefacts and systems with substantial “soft” input), and ii) new organisational routines at customers. Typically new systems for relations with other suppliers and authorities, enabled through engineering companies’ total contract responsibility (so called Engineering, Procurement, Construction, Installation - EPCI contracts).

In the following paragraphs, we will discuss how such innovations emmanate. 3.2 is an introduction to the relation between industry dynamics and innovation capabilities. 3.3 look at technological change and consulting engineering industries, whilst 3.4 presents organisational changes in the Norwegian petroleum sector.

The relation between industry dynamics and innovation capabilities

In general, Norwegian engineering consulting (onshore as well as offshore) seems to go through cyclical upswings and downswings. There are turbulent periods with high merger & acquisition activity and many people being led off from the biggest companies. This is followed by a slow reconstruction of the sector as independent consultants start up small entrepreneurial consultancies by finding alternative niches and building up business during new economic upswings. Some of these are again merged into bigger companies, and so the cycle runs. A period like this took place in Norway from 1988 to 1992, due to prospects of a reduced activity in North Sea petroleum exploration activities. This affects the long run stability of the companies, and their ability to innovate.

Do the small companies and the start ups represent an innovative force in the industry? New business often take departure in a new idea of a service product, and are thus innovative in that sense. But more often their strength is the offered personal expertise that has been gained through hands on experience as staff at one of the bigger engineering or oil companies. The innovative capability is therefore usually manifested in continual incremental innovation, typically providing special tools (and the expertise to use them), bottle neck solving and design of special parts for client.

Even though it is perceived as a threat to important knowledge bases and accumulation of expertise, modification of the sectors “state of the art” skills and knowledge areas through up and downswings can also trigger genuine innovative activity (and not only establishing of new firms). This because it forces the small entrepreneurial consultants to find new markets and closely follow new trends among potential clients which might represent a new upswing. Recent examples that illustrates this point is the developments of new services such as niches within “environmental consultancy”, “quality education services” and the fast growing ICT-consultancy sector, explored by small consultancies that have acquired new knowledge and expertise (“new to the market”) for the purpose. Still, low barriers to entry during these entrepreneurial periods causes fragmentation, and, as mentioned the price cutting does in general reduces a firm’s capability and incentive to invest in innovation. The quality of the services on engineering projects may also suffer and in extreme cases lead to “the winners curse”, where firms bids below project costs and face losses that might be lethal.

As pointed out in Chapter 1, it is not difficult to find examples of new technology and innovation among companies involved in the offshore oil & gas industry in the North Sea. Traditionally, the oil companies have been in the centre of this activity; they are huge organisations which undertakes - or have prime responsibility for - most all kind of activity related to development and extraction of oil & gas-fields. But for these oil companies, engineering consulting enterprises have all the way from the beginning in the late 1960’s, been a very important source of knowledge and skills for implementation of various technical innovations. Despite many examples of crucial technological concepts developed by engineering consultants, the most important contribution to innovation by these knowledge intensive business services, is probably the continual change, the *incremental innovations* that makes technological systems work – or work better.

Technological innovation

Knowledge transfer

Engineering services are maybe more than anything else centered around transferring knowledge to customers, knowledge that is *enabling* innovation. This knowledge transfer is of course a result of both the ability of engineers to disseminate the knowledge *and* the ability of potential users to absorb it. These two processes can often not be sharply distinguished from each other. Hence, the answer to how successful innovation is in customer companies is to be found by investigating to what extent interactive learning between the engineering consultant and its customer is facilitated. Interactivity will at any rate be crucial. This is so because the process of selling a knowledge service - which very often only can be specified accurately after it has been delivered - naturally requires a learning dialogue between supplier and customer in order to be successful at all.

The most classical problem in knowledge transfer is that consultants deliver a “closed” knowledge that can be hard to distribute within the customer organisation. This is called hampering the learning and knowledge transmission process. This problem also relates to the fact that customers seldom follow up consultancy services with internal technical groups to fully exploit what they have paid for. A perception of consultants as somebody that comes suddenly, disappears swiftly - taking some knowledge with them, leaving behind them a standardised and expensive product which is hard to really exploit, can be found among some of the typical offshore customers.[9] In the following we will give two concrete examples of innovations in the offshore industry where engineering consulting has played an important part.

Project management and proprietary construction techniques

On large projects, workers might be idle for two-thirds of the time, waiting for materials or legislative procedures. Knowledge in the form of proprietary software solutions for planning and management as well as in personal expertise can reduce costs substantially. This software is often directly integrated with existing software for drawing and technical specifications related to construction

[9] There is a wide range of innovation literature relevant to the discussion on how knowledge transfer between consultant and customer occurs, notable on the issues of *codified (or explicit) vs. tacit knowledge;* Nonaka 1991, Senker 1995, Foray & Lundvall 1996 and Cowan & Foray 1997. This literature suggests that the consultants codifies customers knowledge and extract knowledge of general relevance which feeds into consultants codified knowledge base. This is in turn used in interaction with customer-knowledge again, making these consultancy service transactions into learning cycles where ideally both parts benefits. In these interactive learning processes *tacit* knowledge might be just as important as explicit knowledge.

and installation. Here, knowledge on automation of procedures is an increasingly important basis for consultant services. This knowledge base is firmly related to the national public knowledge infrastructure (engineering education and research institutions such as SINTEF). The impact of service deliveries in this area is quite impressive: By tailor made computer-aided design and drafting (CADD) software systems, productivity in the design process of oil installations is tripled, reports interviewees in the offshore industry.

CADD systems developed and serviced by consulting-engineers are good examples of new service technologies that enables both service producer and customer to innovate. The interactive innovation process is here actually embodied in the software itself:

New *interactive* CADD systems have software that maintains an on-line database and automatically issues changes notices, revised drawings, and updated bills of materials. Further, consulting-engineers and customers are together using systems that tie CADD systems directly into construction software for estimating, project scheduling, cost control, and materials tracking[10].

The case of STL and STP technology

A good example on the interactive nature of innovation processes between engineering consultants and oil companies, can be found in the development of so called Submerged Turret Loading (STL) and Submerged Turret Production (STP) technology that have been taking place since 1990.[1] The history of this technology in brief is; while waiting for oil pipes to be led out to the biggest oil field in Norway, an ad hoc solution was found, which eventually became the permanent solution. The nature of the development of this system is rather typical for the evolution of technical systems in general, and illustrates how difficult it can be to plan - through a linear innovation process - how one is to reach the optimum technological solutions.

When planning the so called Statfjord oil-field, a pipeline was intended to be built in order to transport the oil ashore. This took time, and meanwhile shuttle-tankers where used, which connected to the oil platforms through *buoys* in order to load the oil aboard. There where however difficulties with the connecting and loading; lack of standardised connections and problems with loading in heavy sea made the method ineffective. *The solution* came to be a standardised buoy connected to flexible risers (small pipelines) under the sea surface (thus “submerged turret”, or buoy) which could be dragged into the front ship of the tankers and connected in a rebuilt room with some special equipment for the purpose (including a Geographical Dynamic Positioning System).

The idea and main drive behind the project came from a technician in Maritime Consulting Group (MCG), a larger Norwegian engineering consulting company. But the development involved an intricate network of people from Statoil - the state owned Norwegian oil company - and Advanced Production Loading Systems (APL) - a joint venture between Statoil and MCG. Later, the concept was taken further by introducing the possibility to add *oil production equipment*[1] in the ship's connector-room.

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[10] This technological and organisational development is very much tied to the ongoing process of cutting costs in Norwegian offshore oil & gas industry (the so called NORSOK-process).

It was introduced by a senior in Statoil, who was a former chief executive of engineering consultants Framo Engineering, which eventually came to be the co-designers of the system, with several technicians and managers involved in the above mentioned development network.
The importance of this network in the innovation process is stressed in a report from the Norwegian Centre for Research on Economics and Business Administration (SNF, 17/96); most of the *core network* in the development of the technology - consisting of some 57 people - was already well established at the end of the 1960's, more than 20 years before the idea of the concept as it came to be was born. In other words we see that inter-personal relations constitute a back bone for the knowledge-transfer back and forth between service supplier and customer in the development process.

Social networks

Social networks very often seem to be a key to explaining the interactive nature of the kind of technological innovation in the offshore industry involving knowledge intensive business services like engineering consultants. As we have already mentioned, *trust* is essential when dealing with the often high levels of uncertainty in the offshore industry. Moreover, we know that when developing complex products and processes, experience shows that very few companies are able to single out the recourses required alone (e.g. von Hippel 1988 and Teece 1987). It is necessary to connect to complementary knowledge elsewhere. This could of course be done formally by putting up a strategic alliance or joint venture, like the late phase establishment of the joint venture company APL in this case. It could also be done by through employees social networks, which in our case constituted the basis for the innovation process and the later stage contractual co-operation.

Organisational innovation

"...the process of innovation is the invention and implementation of new ideas*, which are developed by* people*, who engage in* transactions with others *over time within an* institutional context*, and who* judge outcomes *of their efforts and act accordingly."*

(Van de Ven and Huber, 1995)

We have suggested that organisational innovations are just as important as technological innovations in the offshore industry. Here we will try to identify and analyse this sort of innovative activity.

Project management innovations at customers

It has long been known that on big projects, such as the construction of installations for oil-production offshore, simply waiting for materials, human expertise or approvals accounts for a substantial part of the total engineering costs (Global Oil Report, 1992). Thus it is clear that *project management innovations* represents an interesting way of reducing costs and improving quality.

Larger engineering consultants and oil-companies work with several independent databases dedicated for different stages of the project, from design to fabrication and installation. With emerging computer-based construction management systems it is possible to integrate these databases and improve productivity and lower costs by smoothing the flow of work. This development is a T-KIBS innovation; consulting-engineering companies have been developing these systems together with software suppliers and the oil-companies, resulting in substantial improvement of engineering in terms of costs and delivery time. However, these novel project management systems are first and foremost an organisatoric innovation for the oil companies (and other large customer companies).

The changes at customers through the use of these new information systems have been one of the reasons for the moving towards out-sourcing of project management and the issuing of so called *turn-key contracts* or *EPCI (Engineering, Procurement, Constructiona and Installation)*, which involves total project responsibility until the installation is finished, so to speak with the key in the door).

Organisational innovations as a crucial force in national industry restructuration

"The major changes comprise the following: Operators have increasingly preferred awarding large integrated contracts - the so called Engineering, Procurement, Construction and Installation (EPCI) - to lead contractors; at the same time reducing the size of their own project teams: so contractors have had to assume greater responsibility for developments."

Ingebrigt O. Moum, President of Kværner Oil & Gas

Organisational innovation is, as a matter of fact perceived as a major challenge for the whole Norwegian offshore petroleum industry. We will now briefly sketch some changes which implies innovation in the engineering sector.

Transaction efficiency

Knowledge transfer from subcontracting engineering consultancy usually comes with a heavy documentation that is required by customers to make sure that they get exactly what they wanted, and by authorities for safety reasons. This does not seldom account for 20-25% of a delivery's costs. One may say that this is a part of the service/engineering product, but this is also a part of the transaction costs in the sense that the documentation works as a necessary codification of knowledge so as to give the customer a preview of the product. This is important because the whole service product from an engineering consultant in offshore-projects usually can not be evaluated until long after the construction of an offshore installation (the product is to make the part of e.g. a production platform work, not just to deliver and disappear).

However, the very detailed approval system including authorities (all the way up to the government) and complex legislative bureaucracy is not normally the best way of ensuring innovative knowledge transfer. There is a need for some sort of vertical integration and network relations that can solve the immense uncertainty that offshore engineering usually imply. It might be that a high level of R&D has been sustained by the oil companies that specify the technology they want from sub-contractors, and that niches for technical solutions that needed to be protected in the introduction where provided by this top-down system. But besides the fact that innovation normally seems to be performed best if the producer and maintainer of the technology (engineering contractors) at least is involved in the innovation management, this process is far to costly to be sustained into the future of Norwegian offshore activity.

Increased competition through standardisation of technology and services

A report from the Norwegian Oil Industry Association concludes that of the 900 million dollar yearly investments on the Norwegian continental shelf, it should be possible through reorganisation of construction projects, to achieve a 370 to 450 million dollar cost reduction (40 to 50%). This sort of restructuration for increased cost efficiency ultimately implies technological as well as organisational innovations. The “reform” will especially include implementation of new standards in the interface between suppliers and oil companies. This might stimulate innovativness in the way that suppliers are given the opportunity to add to their products and services the experience and knowledge that more open and standardised specifications allow. The former practice by the oil companies has been to go out in the market with very detailed specifications of the products demanded. The recent discussions on moving towards performance specifications, might in time transfer more of the responsibility for a satisfactory design into the hands of the suppliers, thus moving innovation activity from oil company R&D to a more competitive environment.

Conclusion

We have seen that the engineering consulting companies has a strong influence on the technological capability of Norwegian petroleum actvities. The nature of consulting engineering services are highly focused on knowledge transfer and problem-solving, which means that this service in an extremely large extent represent the innovation force in the Norwegian petroleum complex. The intensive use of such services also indicates that the petroleum acitivities are more innovative than most other Norwegian industries.

Consulting engineering companies represent strong imperatives in both technological and organisational areas. We have shown that the interactive networking between oil companies and consulting firms in many ways represent an advanced mutual learning process (Lundvall ibid.), and that this way of cooperation have resulted in concrete technological developments (the STP example).

Development of the EPCI contracts, which implies that consulting engineering companies become in charge of a total entreprise (engineering, procurement, construction and installation) prooves that consultants also have a central role in organisational developments in Norwegian petroleum activities. In addition, the very existance of the EPCI contract strongly underlines the knowledge complexity that such organisations hold.

Summary and Issues for future Policy

North Sea oil and gas exploitation activities requires a high degree of technically advanced engineering services compared to most other onshore activities. By licensing out exploration of fields, the government has ensured that large subcontacting networks have been established, so as to develop the domestic technology and knowledge bases. In these networks the engineering consulting companies, large and small, have a crucial position. Such knowledge intensive business services are very much linked to manufacturing industry and its ups and downs as well as current production modus (type of products and processes) and economic performance. Thus the offshore petroleum industry is so far no exception to the strong claim made by Stephen Cohen and John Zysman; "There is absolutely no way we can lose control and mastery of manufacturing and expect to hold on to the high-wage service jobs..." (Zysman and Cohen, 1987).

Networks and knowledge production

This study's investigation of the nature of innovation processes within the offshore industry and the influence of engineering consulting in these, suggests that knowledge is not a usual commodity that can be dealt with by using tools from traditional macro-economic models of markets and international trade, when developing economic policy. This implies that:

1. It is important to acknowledge the often strong economies of scale in the production and use of knowledge in the offshore industry. This raises the question; can we apply different policies to manufacturing (i.e. oil companies) and service firms (i.e. engineering consultants) respectively, as long as the difference between their business activities are getting blurred with increased scale?
2. Markets handle commodities (in the form of objects) well, but they do not handle non-commodities (knowledge and information) with the same efficiency. Thus, the production of knowledge will create waste from duplication in a pure economic system of competition (Foray, 1995).
3. This results in firms engaging in filièrs or networks where knowledge clusters facilitate the use of "waste" knowledge, creating synergies between firms and sectors, e.g. as we have witnessed has been the case between oil-companies and consulting-engineering firms.
4. These filières are defining (region and technology specific) regimes within which innovation is taking place, and are thus constituting an important "medium" that can be acted upon by policy means, in order to improve innovativness of the involved industries.
5. The network concept should also be expanded to include relations between individuals in companies (which engage in filières): Employees with special technical knowledge very often also have a social network of colleagues, which in some cases are crucial for the innovation process (i.e. the STL/STP example). This underlines the importance of *social capital* in innovation;
   - The need to stimulate communication between and mobility of professionals in filières.

- Providing a certain entrepreneurial freedom in companies so that employees can develop ideas in together with external partners if appropriate.
- Being aware of social capital when recruiting personnel.
- Making sure that employees follow external training, visit fairs etc. to meet other professionals.

It seems important to develop models for supplier-producer-customer relations in offshore projects. This in order to stimulate knowledge transfer as well as making it easier for the smaller companies to develop their ideas into innovations through R&D joint ventures or other ways of financing. Examples that illustrate this importance can be found in e.g. export of knowledge intensive technological and service products: in order to take on large engineering contracts abroad it has become usual for Norwegian companies to join forces and deliver goods and services (such as hydropower or oil & gas installations) through long term project-based alliances, making vertical integration a necessary way of responding to scale requirements as well. And example of a public policy measure that is applied to promote this, is the Norwegian state owned oil company (Statoil) and the Ministry of Business and Trade bringing along "clustered" technology suppliers to new oil and gas exploration and exploitation areas in the Persian Gulf and former USSR.

Coalitions and joint ventures between *competitors* is also a interesting option in industry policy. The most well known strategic partnership for export among consulting engineers in Norway is the Norconsult (founded in the late 1950's) with some 15 parent company partners at the most. Norconsult has proved to be a strong pool of knowledge for export of engineering services and illustrates the possibilities of coalition strategies.

Education and competition

Finally we will conclude by summarising two main policy areas influencing engineering-consulting's role as mediator of innovation in offshore oil & gas industry:

- ♦ Human capital; there is already a desperate need for more qualified engineers to work within the industry in Norway, and the situation is going to be dramatic within the next few years if policy towards education and training is not changed.[11]
- ♦ Structural changes of the industry, partly formed by initiatives like NORSOK (joint public and industry policy) and partly depending on new directives for competition from the EU.

In this last discussion of policy aspects related to engineering consulting we will concentrate on issues related to the last point: How can the industry sustain in-

[11] Engineering companies in Europe are already looking for alternative sources of competent people in Asia, in the same manner as IT-companies in Norway are doing. The Norwegian business daily *Dagens Næringsliv* writes on the 29. November that "there simply aren't any qualified engineers for the offshore industry in the European Economic Agreement Area."

novativness in a business where the prime goal for a contractor is to win tender-competition by offering solutions based on cheapest possible prize per our services and not by co-operation where best *total* solutions are sought together with customer. We have already suggested that total contract responsibility (through EPCI-contracts) is one solution that will result in increased mergers and acquisition activities because scale and up and downstream integration. The other development, which seems to be more likely in the Norwegian case, is *project-oriented networking* (as opposed to the preceding fixed sub-contracting agreements). This implies looser co-operative agreements between all chains in the offshore industry (from basic supplier to oil company) in order to find innovative solutions that improves margins, while at the same time competing according to European Economic Agreement regulation.

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STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitikk og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group’s work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.