Oil-related producer services and productivity - the case of Norway

Hildegunn Kyvik Nordås and Ola Kvaløy

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1 Introduction[1]

In this paper we analyze linkages between oil companies and service suppliers. The nature and importance of producer services at the various stages of upstream offshore oil and gas exploration and production is presented and analyzed. The paper gives a description of the development of Norwegian oil-related service market, which forms the basis for an analysis of producer services' contribution to technological progress and cost effectiveness in the petroleum sector.

We discuss four recent developments that affect the oil-related producer services market. First, technical developments, particularly within communication technology, have made services separable from goods production to an increasing extent. Engineering services, for example, were largely provided by the major contractors and the oil companies themselves in the early days of petroleum production, while we see a development in the direction of specialized engineering firms in recent years. The second development addressed in this paper is strongly related to the separability of services. As services have become separable from goods production and construction, services have also become more tradable and traded. There has therefore arisen a need to include services in regional and multilateral trade agreements. Both NAFTA and EU/EEA have incorporated services, and the World Trade Organization (WTO) introduced services to the multilateral trade agreement for the first time during the Uruguay Round. This has led to more competition and a more open markets in the service industries, including oil-related services. Third, as offshore petroleum extraction in the North Sea has matured, a higher degree of standardization has occurred. This has partly been a deliberate industrial policy initiative that has been implemented through the so-called

[1] Thanks to the Norwegian Research Council, "Næring, Finans og Marked" for financial support, the Official Statistics of Norway for assistance in providing unpublished data and Gaute Torsvik for useful comments.

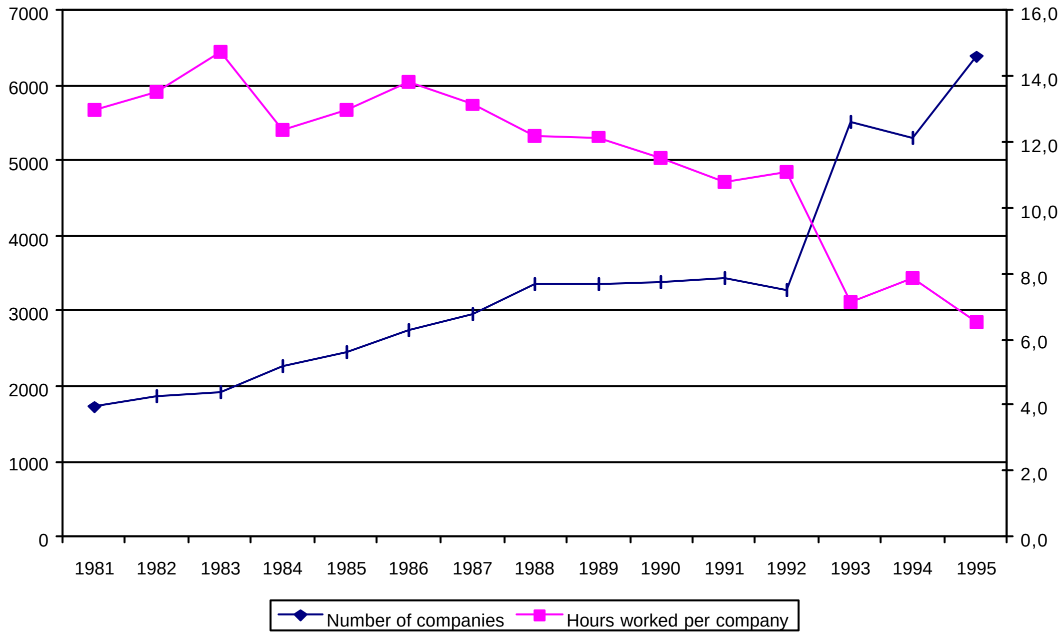
NORSOK process.[2] A larger degree of standardization is another contribution to open markets and competition. However, the NORSOK process envisages standardization related to *functions* rather than products (NORSOK 1995). Standardization of functions may result in clusters of products that fit each other as hand in glove and thus constitute a technological parcel. Other products filling the same functions may not fit into this particular technology, at least not unless adjustments are made. These features may generate widespread use of tailor-made technology to specific oil fields and implicit or explicit long-term contracts between oil companies and their suppliers.[3] The world market for oil-related services is dominated by a small number of very large oil service firms that provide life cycle field development services to the oil companies. Nevertheless, there has been a proliferation of specialized niche suppliers, as figure 1.1 below indicates.[4] It shows number of companies (left-hand scale) and average size represented by thousands of man-hours worked during the year (right-hand scale). Clearly, there has been a large increase in the number of firms and a sharp decline in the average size of the firm within the technical services sector since 1980.

[2] NORSOK is a Norwegian abbreviation for "the competitiveness of the Norwegian continental shelf". It is a joint effort undertaken by the Norwegian oil companies, the offshore supply industry and the Norwegian government in order to reduce costs and standardize the production processes on the Norwegian shelf. A similar project, the CRINE project has been implemented in the British sector of the North Sea.

[3] See Nordås (2000) for a discussion of tailor-made versus standardized inputs.

[4] The figure presents data on technical services in general, not only oil-related technical services.

Figure 1.1: Number and average size of companies in the technical services sector



Source: Official Statistics of Norway

Standardization in industries characterized by economies of scale probably leads to larger companies exploiting economies of scale. More open markets and standardization on functions, on the other hand, create scope for small niche producers of specialized inputs. Both developments should enhance productivity in the petroleum sector. The fourth recent development that affects oil producer service market is the historically low oil prices experienced during 1998/99. This created pressure for reduced costs and an incentive for process innovation. Ideally, firms minimize costs irrespective of the price of its output. In practice, however, it appears that squeezed margins induce cost-saving process innovation.

Our study of service inputs' contribution to productivity is limited to the oil companies' upstream activities, e.g., the extraction of oil and gas. The rest of the paper is organized as follows. Section 2 briefly outlines the theoretical background for the paper. Section 3 describes the relative importance of service inputs during three phases of oil companies' upstream activity: exploration, development and production. Section 4 presents and discusses data on Norwegian trade in oil-related services while section 5 presents some preliminary estimates of the contribution of producer services to productivity in the petroleum sector. Section 6 concludes.

2 Theoretical background

The empirical analysis and discussion build on two strands of economic theory. First, it builds on production and growth theory, focusing on the role of intermediate inputs in enhancing productivity. Second, it is related to Porter's theory of industry clusters as vehicles for enhancing productivity and competitiveness. The two strands of theory are closely related as clusters constitute a network of companies providing inputs to each other and a common pool of skills.

An industrial cluster as defined by Porter (1990) constitutes a number of competing companies, their upstream suppliers of inputs, downstream customers who process or market the products, and finally related research and development (R&D) activities. Horizontal competition among companies provides incentives for innovation and cost effectiveness. There is therefore a constant pressure on upstream suppliers to improve the quality of inputs and reduce costs. A common pool of skilled workers and output and spillovers from R&D activities facilitate process and product innovation. The industrial cluster is thus characterized by a dynamic interaction between firms and markets that represents a virtuous circle. Reve et. al. (1993) find that the oil and gas industry constitute a cluster in the Norwegian economy, while the offshore supply industry constitutes another cluster. The latter is of course closely related to the oil and gas sector and would probably not exist without it. However, the offshore cluster is built on historically important and competitive Norwegian industries such as shipping and shipbuilding. A number of companies within these two industries restructured and reinvented themselves as offshore companies during the 1970s, a process that was driven both by the opportunities the development of a Norwegian oil and gas industry provided, and the crisis in the shipping industry at the time.

In spite of the findings that both the oil and gas industry and the offshore industry are clusters and thus operate in a competitive environment fostering innovation and cost effectiveness, it has become increasingly clear that the Norwegian petroleum industry has a cost problem (NORSOK 1995, NOU 1999:11). Nordås (2000) argues that this is because the Norwegian market is too small to exploit economies of scale and provide a sufficient diversity of inputs at the same time. This argument is based on insights from production and growth theory where productivity is determined by the quality of inputs on the one hand and the degree of specialization on the other hand. The theory has its roots in classical economics as developed by Adam Smith and Alfred Marshall, and has more recently been formalized and further developed by Grossman and Helpman (1991), and Young (1998), among others. The theory can be briefly outlined as follows. The production function of a company is represented by equation 1:

$$Y = AK^{a}\left(\sum_{1}^{n} l_i x_i\right)^{b} \qquad (1)$$

The left-hand variable Y represents production of oil and gas per hour of labor input, given in mtoe;[5] A is a technology parameter indicating the general level of technology and business conditions in the industry, K is capital employed in the petroleum sector per hour of labor input; n is the number of suppliers of goods and services to the oil company, l_i and x_i

constitute the quality and the quantity of input i respectively. An increase in the quality parameter, the technology level, or the number of inputs leads to an increase in output for the same quantity of inputs K and X where X represents the total quantity of intermediate inputs. When it takes costly R&D efforts to improve quality of inputs, the size of the market and the market power of the innovators determine the expenditure on R&D. By the same token, when intermediate inputs are produced subject to economies of scale, the size of the market determines how many differentiated producers of components and producer services that can be accommodated.

Section 4 presents some tentative empirical estimates on the role of oil-related services in improving productivity in the oil and gas sector, based on Norwegian data. We focus on two parameters, the general level of technology, A and the degree of specialization, n. We interpret A as a factor affecting the productivity of capital input, e.g., the production capacity per krona invested in extraction and production equipment. We use the number of companies supplying oil-related services, n, as a measure of the degree of specialization. But before we continue with an econometric analysis, we present data on the role of services as inputs in the exploration and development of an oil/gas field and extraction of oil and gas.

3 The three phases of oil and gas extraction

The upstream oil and gas extraction activity can be divided into three technologically and operationally separable phases: exploration, development and production.

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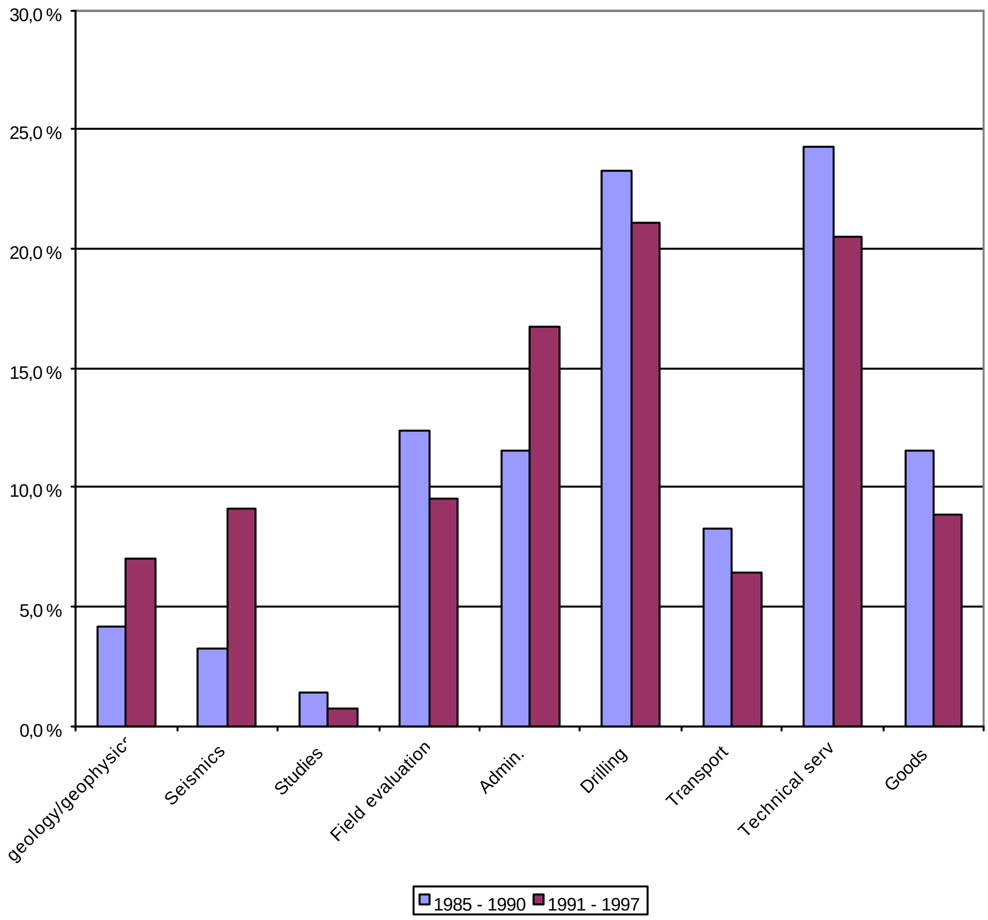
[5] Mtoe = millions of tons oil equivalents.

3.1 Exploration

The service intensity is most prominent during the exploration phase. Figure 3.1 shows different categories of services' average share of total exploration costs during two periods of time.[6] From the figure we can see that the service share of total exploration costs increased from 88.4 to 91.2 percent between the two periods. Note that exploration costs have been shifted towards the early stages of exploration, e.g., the cost shares of geology, geophysics and administration have increased at the expense of costs later in the exploration phase. This indicates that the oil companies spend more resources on planning and that a larger part of the analysis of the reservoir takes place before exploration- and limitation wells are drilled. The reasons for this development are probably both developments of seismic technology and data software that have improved the analysis of the reservoir immensely, such that the size and properties of the reservoir are much better known before drilling. Geophysical discovery techniques and 3D software have also improved discovery rates and reduced discovery costs substantially (Elf 1998). On the Norwegian shelf, however, reduced discovery costs have only materialized during the period 1990 to present, after a sharp increase in the late 1980s (NPD 1999).

[6] The cost shares vary substantially over time due to large projects and the fact that service inputs in each project varies over time. We have therefore chosen to estimate averages over a 5-year period of time.

Figure 3.1: Investment costs during the exploration phase

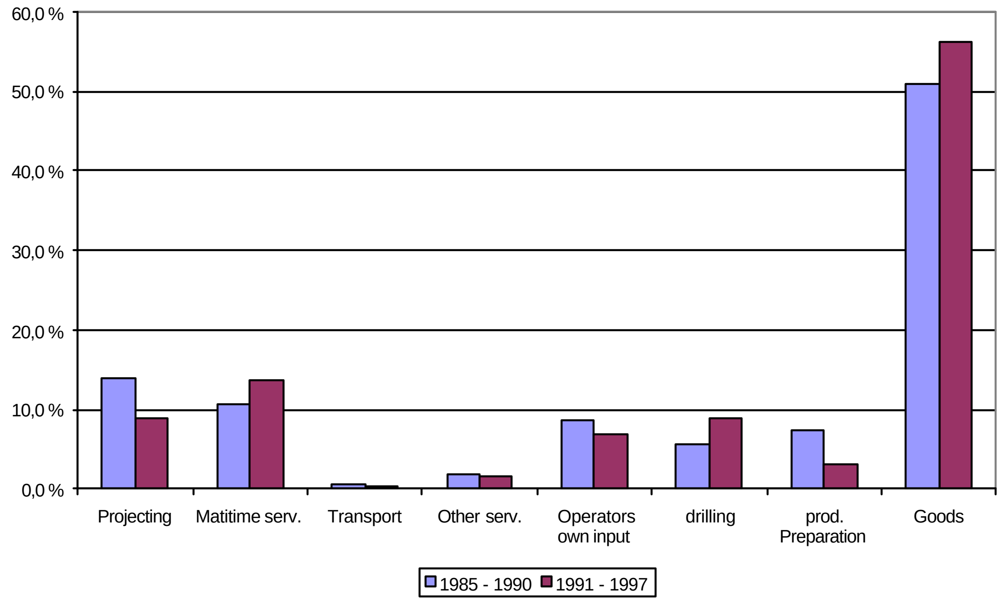


Source: Official Statistics of Norway.

3.2 Development

The process of choosing extraction technology starts during the exploration phase and continues during the development phase. Engineering services related to projecting and production preparation; and maritime services are the most important services during the development phase. Engineering services are produced internally in the oil companies, by the major contractor and by subcontractors, while maritime services are mostly provided by specialized oil service firms. Figure 3.2 shows different services' share of total investment costs during the development phase. Compared to figure 3.1 it is clear that the development phase is much less service intensive than the exploration phase. Further, we see the opposite development over time when it comes to the relative importance of goods and services. The relative share of services has actually declined in the development phase. Note also that the share of total investment costs that stem from the oil companies' own production of services has declined, a trend that suggests that oil companies have outsourced services. They have done so among other things by a more widespread use of so-called EPCI contracts between the oil companies and their major contractor.[7] Such contracts leave a larger share of engineering, procurement and testing to the contractors.

Figure 3.2 Investment costs during the development phase



Source: Official Statistics of Norway

Project leaders from Statoil and Aker Engineering interviewed during this project explained that the decline in the cost share of engineering services is by and large due to a substantial reduction in the number of engineering hours per ton constructed, and thus represents a relative productivity improvement. Probable reasons for the relative decline in projecting costs are learning effects and economies of scale, since a number of oil platforms had similar technology and design. During the development of the Gullfaks field, a significant oil and gas

[7] EPCI is an abbreviation of engineering, procurement, construction and installation.

field developed in two stages over a time period of about 8 years (from 1982 to 1990), it was for example decided to build the Gullfaks C platform as a blue-print of the Gullfaks A platform in spite of the development in offshore extraction technology that had taken place between the two projects. Lower investment costs due to economies of scale and experience were considered more important than possible, but uncertain lower extraction costs by using more recent technology in this case.[8] EPCI contracts may also have improved efficiency through better coordination, although a recent study finds that the major contractors have had difficulties with switching to EPCI contracts (NOU 1999:11).

3.3 The production phase

Conditions are more stable over time during the production phase, and the cost share of each input does not fluctuate to the same extent as it does during the exploration and development phases. We have therefore chosen to analyze the input-output tables produced every fifth year in order to track trends and developments in service inputs during the production phase. However, since the oil price is very volatile, and input-output tables are given at current prices, the input-output coefficients vary a lot over time. We have therefore chosen to show in table 3.1 the percentage share of each sector in *total intermediate demand* (not the share of total gross output).

From the table we can see that the cost share of services, including imported services, is relatively constant over the period, albeit a slight decline can be observed. There has, however, been a change in the composition of service inputs over the decade analyzed. Services related to oil and gas have declined sharply. This is due to the fact that this category includes exploration and limitation drilling, which have been shifted forward to the

[8] Interview with the project leader for the Gullfaks development in Statoil.

exploration and development phase and are therefore reclassified as investment in the national accounts. The largest cost share unsurprisingly goes to payment for technical services, while other locally produced services account for the largest increase over the time period reported. The latter includes maintenance, upgrading of existing equipment and to some extent process innovation. Maintenance is increasingly undertaken by the contractors or outsourced to specialist firms. Thus, there have been several new establishments of firms in the maintenance market recently.

Table 3.1: Intermediate inputs during the production phase

Sektor	**1985**	**1990**	**1995**
Local goods	27.3	31.6	35.5
Extraction of oil and gas	6.8	10.8	14.3
Services related to oil and gas	3.6	0.8	0
Electricity and water	0.3	0.2	0.4
Construction	0	0.6	0
Retail trade, wholesale trade, hotels and rest. Etc	3.8	3.7	2.5
Transport and communication	7.5	8.7	9.6
Financial services	2.2	1.6	1.2
Data processing	1.0	1.1	0.9
Technical services	14.9	13.9	13.6
Other local services	6.6	5.9	9.9
Imports of goods	9.4	6.2	4.9
Imports of services	1.4	2.1	2.1
Other imports	15.1	12.5	5.0
Total	100	100	100

Source: Official Statistics of Norway

As the oil fields mature, demand for production and reservoir engineering increases steadily. Service suppliers in this category provide seismic and technical analyses of fields in operation, identify the gap between installed technology and state of the art technology, and finally modifies the production process in order to narrow the gap as much as possible given the limitations of installed equipment (Schlumberger 1997). New technology enables the oil companies to improve recovery rates from the reservoir through better placement of the wells and better understanding of how the reservoir changes during production. The maturing of the Norwegian sector suggests that the cost share of producer services will probably increase in the future.

An interesting trend observed from table 3.1 is the relatively sharp increase in the intra-sectoral trade in the petroleum sector. This could mean increased cooperation between oil companies, and that goods and services have become less specific to the field where they are used. Note also that the relative share of merchandise imports has declined, while imports of services have been stable during the 1990s. The increased market share of Norwegian suppliers of goods can largely be explained by an industrial policy aiming at developing a Norwegian supply industry. The petroleum legislation from 1985 stated that Norwegian suppliers should be allowed preferential treatment if they were competitive (§ 54). Such preference was, however, incompatible with Norway's entry into the European Economic Area in 1995, and the clause was therefore not included in the new petroleum law from 1996. This most recent law does nevertheless state that the petroleum resources shall contribute to the strengthening of Norwegian business and industrial development. In addition it states that the management of the petroleum resources should be implemented with a view to regional policy. The numbers presented in table 3.1 suggest that the policy has been effective, although we can of course not rule out that the Norwegian market share would have been large also without any protection.

3.4 Oil-related R&D services

The petroleum sector is among the industries in the Norwegian economy with the largest expenditure on R&D per employee. In addition, the petroleum sector is distinct from other sectors of the economy by purchasing a larger share of R&D from external, specialized firms. Data on R&D expenditure is, however, not presented in the oil and gas statistics on the three phases discussed above. We therefore discuss R&D expenditure in the oil and gas sector as a whole.

External purchases account for 43 percent of total R&D expenditure in the petroleum sector compared to an average of 26 percent for all industries and 20 percent for all industries excluding the petroleum sector (Frengen, Foyn and Ragnarsøn 1995). This is probably explained by two features of the petroleum sector. First, the sector produces a relatively homogenous product, such that there is relatively low return to product innovations.[9] Therefore, R&D expenditure is mainly directed towards process innovation with the objective of cutting costs. Second, exploration and production technology is largely embodied in machinery and equipment, which is produced by the offshore industry. Therefore, process innovation is undertaken in cooperation with the offshore industry.

To summarize section 3, producer services have accounted for a relatively constant share of total costs in the petroleum sector if we look at the exploration, development and production phases combined, but the service share has shifted towards the exploration phase. The figures, supported by interviews with project leaders both in the oil companies and the offshore industry, indicate that more time and resources are spent on planning and relatively less is spent on services during the development phase in more recent projects. In addition, the most recent trends suggest that the service share is about to increase during the production phase as fields mature, margins are squeezed and the need for maintenance and upgrading increase.

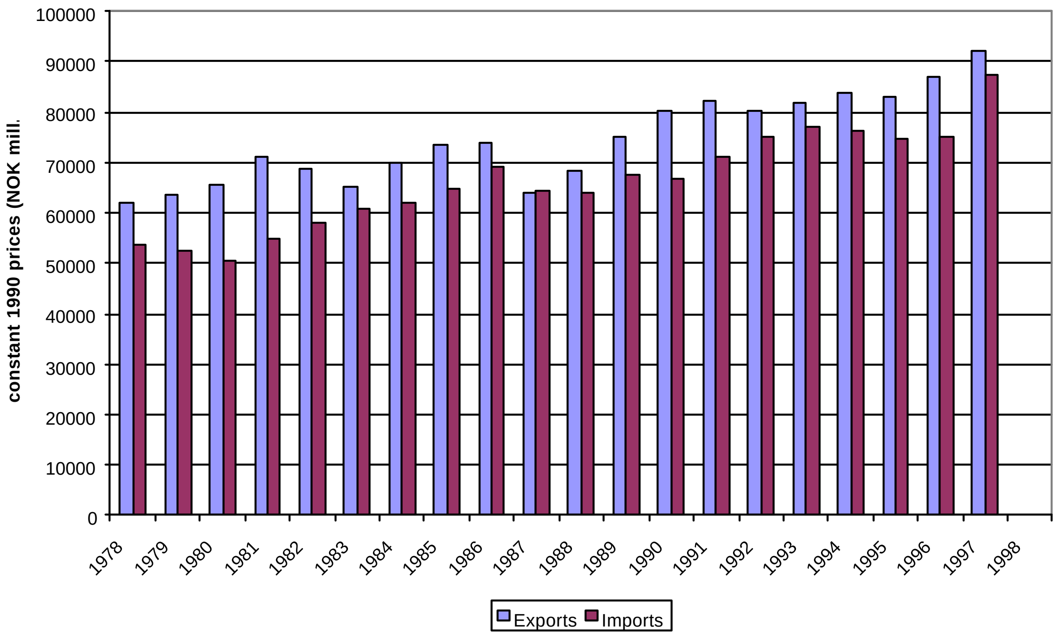
[9] Developing fuels that satisfy increasingly strict environmental regulations is important, however.

4 Trade in services

Norwegian firms have a large market share as suppliers to the Norwegian petroleum sector as shown in section 3. Furthermore, the oil and gas sector and the offshore sector constitute two industrial clusters with strong linkages among them (Reve et. al., 1993). Porter's (1990) theory of industrial clusters predicts that this industrial structure will foster internationally competitive exporting firms in both clusters. This section investigates to what extent the prediction holds for Norwegian oil-related services.

Norway has been a net exporter of services for most of its modern history, mainly due to its shipping industry. Figure 4.1 depicts total trade in services during the period 1978 – 1998 and shows that there is a surplus on trade in service every year except 1987.

Figure 4.1 Norwegian trade in services



Source: Official Statistics of Norway

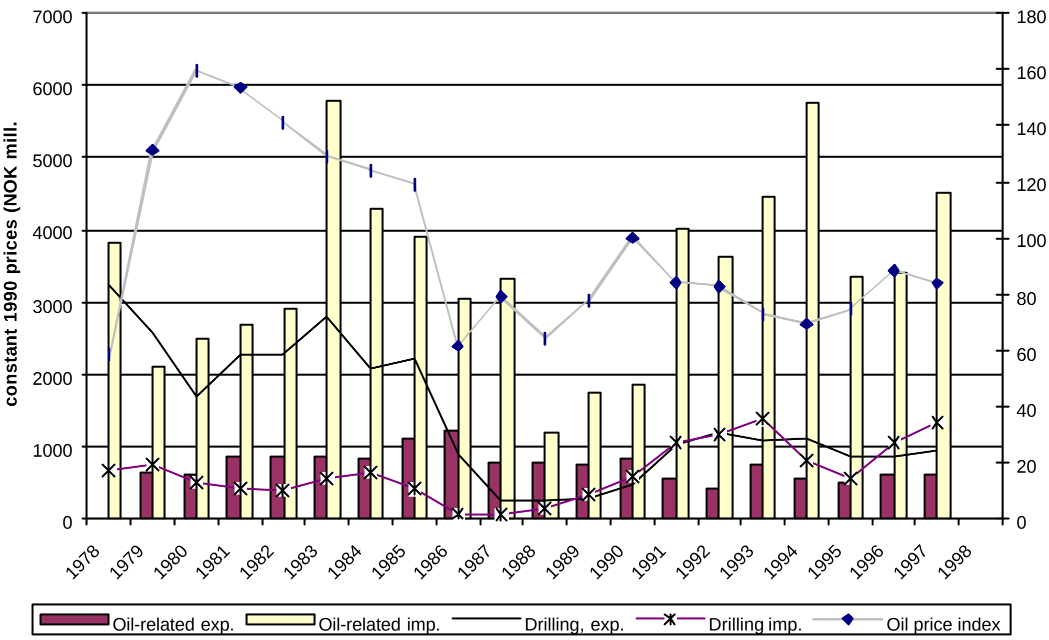
Figure 4.2 depicts trade in drilling services and other oil-related services. The oil price index is shown in the same figure (right-hand scale) in order to illustrate to what extent fluctuations in trade follow fluctuations in the oil price. Norway had a substantial surplus on trade in drilling services during the early days of oil production in the North Sea, while this surplus has narrowed over time and trade has been fairly balanced during the 1990s. It appears that the North Sea is the major market for the drilling companies, and that exports and imports of drilling services change with local demand for such services.[10] Thus, it appears that trade in drilling services is mainly driven by the drilling companies' wish to utilize capacity and smooth production and revenue over time. The initial trade surplus reflects the fact that parts of the Norwegian shipping industry had restructured and established itself in the international rig market very early in the Norwegian oil production era (Reve et. al. 1993). It appears, however, that as the Norwegian market expanded, drilling companies have increasingly focused on the local market.

Exports of other oil-specific services appear to fluctuate with the oil price with a time lag of two to three years.[11] Imports of services fluctuate even more, but are less correlated with the oil price. In spite of a sharp increase in petroleum sector investments and production, the absolute level of imports appears to have fluctuated around a flat trend, indicating an increasing Norwegian market share. There is, nevertheless a large trade-deficit in oil-related services during the entire period.

[10] We found a relatively strong correlation between production in the Norwegian petroleum sector and exports and imports of drilling services. The correlation coefficient was –0.63 between exports of drilling services and oil production and 0.55 between imports of drilling services and oil production.

[11] The correlation coefficient between exports of oil-related services (lagged by three years) and the oil price is found to be 0.64 during the period 1975-1995. Other lags gave a lower correlation coefficient. Exports of

Figure 4.2 Trade in drilling services and other oil-related services

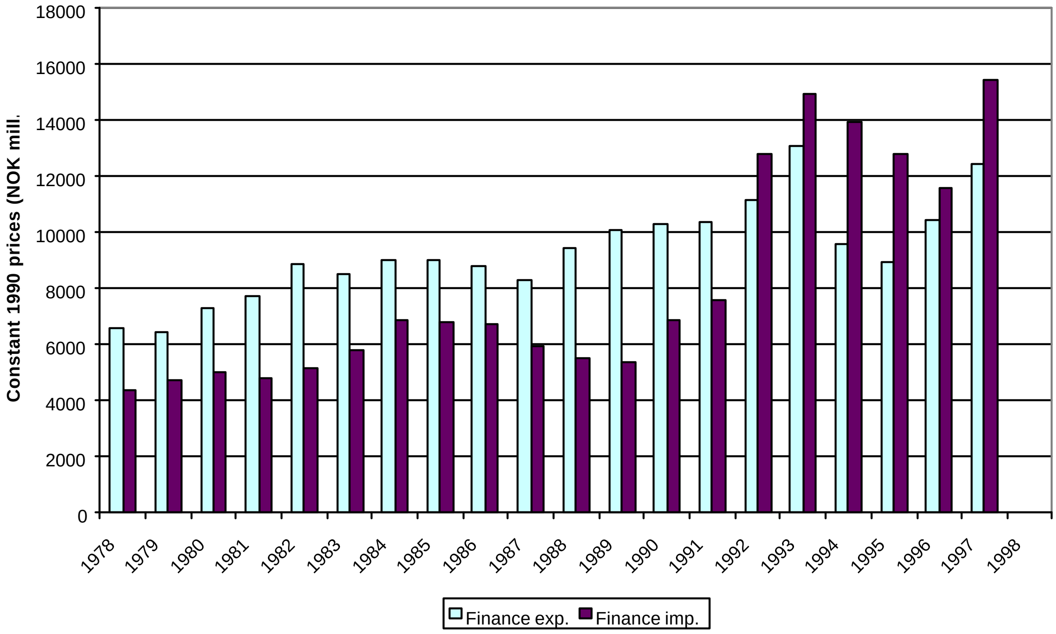


Oil price index: 1990=100
Source: Official Statistic of Norway and IMF

We next turn to financial services. This is a sector that is not directly related to the petroleum sector, but due to the nature of the petroleum sector, it requires sophisticated financial services for its operation. The petroleum sector for example undertakes huge investment projects and manages large and fluctuating cash flows in different currencies. In addition the sector faces more risk related to safety, environmental problems and output price fluctuations than most other sectors in the economy. Based on Porter's theory, it should be expected that demand from the petroleum sector had fostered a competitive and sophisticated financial sector.[12] Figure 4.3 below presents data on exports and imports of financial services during the two decades 1978-1998.

drilling services is correlated with oil prices with a correlation coefficient of 0.54 during the period 1978-98 (with no time lag).

Figure 4.3 Norwegian trade in financial services



Source: Official Statistics of Norway

Norway was, indeed a net exporter of financial services during the late 1970s and the 1980s. Export performance during this period was largely due to exports of insurance services related to the shipping sector. However, in 1992, in the aftermath of a banking crisis that rendered the largest Norwegian banks under state ownership, Norway turned into a net importer of financial services. The petroleum sector has in other words not fostered and internationally competitive financial sector in the same way as the shipping industry fostered international insurance firms.[13]

From table 3.1 we see that the petroleum sector uses technical services relatively intensively during the production phase. We finally assess whether this has fostered exports of technical

[12] This has happened in South Africa where the gold mining industry, which has similar features as the oil industry in terms of demand for financial services, has fostered internationally competitive financial sector firms (Hodge 2000).
[13] The state dominance in the petroleum sector may have contributed to less interaction between the financial sector and the petroleum sector than would have been the case in a more liberal setting.

services. The input-output data, which is compiled every 5 years shows that the export share of technical services' gross output has declined from 6.5 percent in 1980 to 3 percent in 1995. The absolute value of exports of technical services has, however, increased from about NOK 0.9 bill. in 1985 to NOK 2 bill. in 1996, an annual average increase of almost 7 percent a year.[14] Technical services have in other words experienced a high rate of growth in exports, but from a low base.

To summarize this section, it appears that the most oil-specific services, including exploratory drilling, production drilling, seismic shooting and analysis of seismic data have not developed into dynamic exporting sectors in Norway. Trade in these services appears rather to occur during booms (imports) and busts (exports) in Norwegian demand. Nevertheless, Norway has fostered one leading international company in oil services supply, Petroleum Geo Services (PGS), and a number of smaller niche producers that contribute to the relatively high rate of growth of exports in technical services. Outside these niches, export performance is less impressive. Total services exports have grown by about 2 percent annually on average during the period 1978-1997, less than total export growth. This is rather disappointing given that exports of services has grown faster than merchandise exports globally during the same period of time, Norway has a relatively service-intensive economy, and the oil and gas cluster is relatively service-intensive.[15]

[14] Figures are given at constant 1990 prices. They are deflated by the authors using disaggregated data for nominal exports of services from the Official Statistics of Norway (OSN) and deflating by the implicit deflator one gets when dividing current price exports of services and constant price exports of services at an aggregate level. The disaggregated data are not published, but can be obtained from the OSN. The categories of technical services included in the export figures are "Other technical services," "Technical consultancies," and “License and patent fees.”

[15]The services share of GDP is 68 percent in Norway, slightly higher than the OECD average of 66 percent.

5 Producer services and productivity – empirical evidence

An oil-platform lasts for decades once it is installed in a field. It could therefore be expected that the rate of technological progress is slow in the offshore petroleum sector. This is, however, not the case. Technological development has reduced the lead-time from exploration to production and extended the production phase. In addition, the three phases discussed in section 3 increasingly overlap in time. Thus, exploration, further mapping of the reservoirs and new investments take place in fields under production. Lastly, cost-cutting process innovations take place continuously also in existing fields.

In this section some tentative estimates of the service sectors' contribution to productivity improvements in the petroleum sector are presented. We take the theoretical framework presented in section 2 as a point of departure. There are two channels through which service inputs contribute to productivity improvements in this theory of production and growth. The first is through the technology parameter, represented by A in equation (1). If we, somewhat loosely, interpret increases in this parameter as capital-augmenting technological progress, we can study how producer services improve the quality of the extraction and production equipment installed in an oil field. This in turn corresponds to the development phase discussed in section 3.2. The second channel is the degree of specialization during the production phase, for which we use the number of producer service firms as a proxy.

5.1 Improving the productivity of capital

Let us start with the capital-augmenting technological progress parameter A. As indicated in figure 3.2 the relative share of producer services has declined over time, and as stated by interviewees, the engineering hours per ton constructed has declined over time. Both these indicators suggest that service inputs to the development phase have become more productive over time. It remains to find out to what extent this has improved the productivity of capital; e.g.; the production capacity per krona invested.   Denote capital cost per Mtoe of reserves k, and the number of different service inputs during the development phase, n. $\hat{A}$ can be interpreted as a vector of variables that affect the productivity of the capital equipment. We can then represent the investment cost per Mtoe recoverable reserves as follows:

$$k = f(\hat{A}, n) \tag{2}$$

We have estimated this function on data on development costs of 18 fields in the Norwegian part of the North Sea.[16] The 18 fields were developed during the period 1980-94, a period of substantial technological change in the offshore petroleum sector. Moreover, the 18 fields are located at different sea depths and differ regarding the reservoirs' mix of oil, gas and condensate. Several variables were included in order to capture exogenous technological progress and differences in costs due to external factors such as differences in sea depth. The time of production start was used as proxy for technological progress, assuming that this follows a time trend. Sea depth are strongly correlated with the time variable due to the fact that the fields in shallow water were discovered and developed first. However, and perhaps surprisingly, the depth of the field proved to be insignificant in all regressions, whether or not the time trend was included. We also included an indicator, which captures different cost structures stemming from the choice of technology type. We distinguished between fixed installations, floating installations and sub-sea equipment. Finally, we experimented with variables such as the oil price at the time of the Plan for Development and Production (PDP). Also the oil prices at the time of PDP turned out to be insignificant as a determinant of the cost of production equipment.

[16] See the appendix for a description of the data. We have used a simple OLS regression.

The functional form that gave the best fit was the lin-log (e.g. the left-hand variable is given at absolute levels while the right-hand variables are given in logarithms). The regression results are reported in table 5.1 below.

Table 5.1 Costs per Mtoe recoverable resources

	(1)	(2)	(3)	(4)	(5)
Constant	778.9**	-262708	-286602	783.3**	813**
	(4.03)	(-1.69)	(-1.50)	(5.14)	(4.49)
Ln (number of service suppliers)	-140.5**	-142.8**	-152.7*		-26.3
	(-2.70)	(-2.91)	(-2.29)		(-0.33)
Ln (recoverable reserves)				-121.0**	-105.8
				(3.51)	(-1.83)
Ln (year of production start)		34689	37833		
		(1.70)	(1.50)		
Type of installation			20.3		
			(0.23)		
Adjusted R^2	0.31	0.42	0.43	0.40	0.36
N	18	18	18	18	18

** Significant at the 1 percent level
* Significant at the 5 percent level
Type of installation: 1=sub-sea equipment, 2=floating equipment, 3=fixed installation

T-statistics are shown in parantheses. The coefficients tell how a *change* in the right- hand variables affects the *level* of the left-hand variable; e.g., the cost of production equipment per Mtoe to be extracted. The number of service suppliers contributes to lower costs of production equipment per Mtoe in all regressions. The variable is significant at a 1 percent level in regressions (1) and (2) and at a 5 percent level in regression (3). However, when we include total estimated reserves of the field in the regression (column (4)), this variable alone explains about 40 percent of the variation in costs, indicating significant economies of scale in the production of equipment. The size of estimated reserves is strongly correlated to the number of services, with a correlation coefficient of 0.79. This suggests that there is a problem of multicollinearity. Thus, when both variables are included in the regression, presented in column (5), neither is significant but the overall fit of the equation is not reduced much compared to column (4) and it is improved compared to column (1). The results do not refute the prediction from theory that the size of the market determines the degree of specialization and that increased specialization leads to increased productivity. In order to investigate this further, we regressed the total cost of service inputs per Mtoe of capacity on the number of service suppliers. The results are presented in table 5.2

Table 5.2 Costs of services per Mtoe recoverable reserves

	(1)	(2)
Constant	394.7**	5.6**
	(4.26)	(8.79)
Ln (number of service suppliers)	-80.6**	-0.38**
	(-3.24)	(-2.23)
Adjusted R^2	0.36	0.19
N	18	18

The first column presents the result of a lin-log regression while the second presents the results from a log-log regression. The first regression indicates that if the number of service suppliers increases by 10 percent, the cost of services per Mtoe reserves during the investment phase declines by 8 mill. NOK. The second regression indicates that if the number of service providers increase by 10 percent, the cost of service inputs declines by 3.8 percent. The impact of an increased number of service suppliers can be explained both by increased competition among service suppliers and by the theory of productivity improvement through increased specialization among service suppliers. Since we have only 18 observations, the regression results should be taken only as a first indication of services' contribution to productivity improvements in the offshore sector.

5.2 Improving productivity during the production phase

We have now estimated how services contribute to productivity of investments, e.g., reduces the cost of investment for a given production capacity. We next do a similar regression for the production phase. Production from an oil field is typically represented by a bell-shaped curve with a long right-hand tail. Due to limited reserves, production reaches a peak after a few years, remains at a plateau for some years and then starts to decline. In order to capture this production structure, we estimated the following equations:

$$Y_t = a_0 + a_1(t - t_0) + a_2(t - t_0)^2 + a_3 R_0 /(t - t_0) + a_4 n \qquad (3)$$

$$\ln Y_t = b_0 + b_1 \ln(t - t_0) + b_2 \ln(R_0 /(t - t_0)) + b_3 \ln n \qquad (4)$$

Y represents output of a particular field during a one-year period t, t_0 is the production start year, R_0 is the estimated reserves at production start, and n is the number of service suppliers during the one-year period. The equations are estimated using a simple OLS regression on panel data constructed from data provided by the Ministry of Oil and Energy (see the appendix). Given the bell-shaped production path typically found in oil and gas extraction from an oil field, we expect a_1 to be positive and a_2 to be negative. The third term in equation (3) represents the interaction between total reserves in the field and time since production started and thus distinguishes large fields from small ones. The parameter a_3 is expected to be positive. The regression results are presented in table 5.3.

Table 5.3 Production Mtoe

	(1)	(2)
Constant	-12.71**	-1.87**
	(-2.73)	(-2.96)
Time since production start	3.91 **	1.12**
	(5.01)	(6.66)
Time since production start squared	-0.15 **	
	(-4.31)	
Interaction term reserves/time since production start	0.12 **	0.49**
	(3.49)	(3.76)
Number of service suppliers	0.12	0.06
	(1.72)	(0.36)
Adjusted R^2	0.33	0.48
Number of observations	65	65

*** Significant at the 1 percent level*

Column (1) and (2) present regression results from equations (3) and (4) respectively. All parameters have the expected signs, but the number of services is significant only at the 10 percent level in equation (3) and insignificant in equation (4). This indicates that the number of services most likely has an impact on the *level* of output, but less on the *growth rate* of output. If one more service producer, providing a specialized service input, enters the market as a supplier to an oil field, production increases by 0.12 Mtoe, according to the regression results from equation (3). Our regression thus supports, albeit weakly, that the theory of productivity improvements through specialization applies to the Norwegian petroleum and offshore sectors.

6 The impact of liberalizing trade in services

The previous section discussed how increased specialization in the producer service market enhances productivity in the petroleum sector, both indirectly during the development phase and directly during the production phase. An important proposition from the theory of specialization and productivity is that the degree of specialization is limited by the size of the market. The Norwegian offshore market is relatively small and the Norwegian market share in the service sectors is high. In our panel data the Norwegian market share varies from 42 to 100 percent, and the market share is above 85 percent for all the major oil fields. Recall from section 4 that exports of oil-related services outside the technical services category have been stagnant over the past 15 years. Taken together, these figures suggest that increased specialization in the oil-related services sectors depend on more open markets, where local producers export more, and where import penetration in the Norwegian market increases.

Norway became part of the European Economic Area from 1995, and after that there is in principle free trade in services within the European Union. Our regression analysis does not cover data after 1995, but data from the Petroleum Directory and Official Statistics of Norway suggest that there has been no discernible shift in import penetration in oil-related services since 1995. Whether this is due to technological barriers to trade, long-term formal or informal contracts between oil companies, contractors and subcontractors is not clear. However, a large number of the contracts included in the PI database which we used in the panel data presented in the annex is frame agreements lasting 3-5 years. It is therefore possible that import penetration will increase as long-term contracts expire and the present restructuring of the sector, including giving foreign oil companies a larger share of new licenses, takes hold.

In parallel to regional liberalization of trade in services, there is also liberalization on a global level under the auspices of the WTO. The General Agreement on Trade in Services was introduced during the Uruguay Round and further negotiations started in 2000. The GATS comprise four modes of trade in services: i) arms length trade, ii) foreign investment in service sectors, iii) migration in order to provide services, and iv) services consumed in the exporting country by citizens from the importing country. National treatment and the most favored nation principle applies to the GATS. However, so far the GATS only applies to a positive list of sectors or sub-sectors. Moreover, the positive list differs among the GATS member countries as each country is only restrained by its own commitment.

The oil service business is already a global business with a few dominant multinational companies. Their relatively small market share in the Norwegian market is probably more related to the structure of the Norwegian sector than formal barriers to trade in services. The GATS may, however, be important for Norwegian oil-related service firms' access to foreign markets, as these markets mostly lie outside the European Economic Area. In order to take advantage of better access to foreign markets, it is probably crucial to establish relations to multinational oil companies. As argued by Heum and Vatne (1999), one way of achieving this is to give multinational oil companies better access to the Norwegian petroleum resources, which to some extent was done during the recent 16th license round. Both increased import penetration in the Norwegian oil service market and increased exports of Norwegian oil-related services will increase the potential degree of specialization and improve productivity in the Norwegian petroleum sector.

Appendix

Table A.1 presents data on investment costs and their determinants used for the regression on equation (2). Sources of data: Investment costs, recoverable reserves, production start, type of technology, sea depth: Ministry of Oil and Energy (Fact sheet), Number of service suppliers: Ministry of Oil and Energy (the PI database).

Table A.1 Investment costs

Field	Investment cost per Mtoe, NOK mill. (1996 prices)	Number of service suppliers	Production start	Fixed, floating or sub-sea	Oil price at PDP	Sea depth
Brage	181.8	32	1993	30	23.71	140
Draugen	142.0	135	1993	30	14.98	251
Gullfaks	218.2	165	1986	30	36.68	175
Gyda	325.6	30	1990	30	18.44	66
Heidrun	164.8	96	1995	20	19.98	350
Heimdal	268.7	38	1985	30	36.68	120
Hod	95.7	7	1990	10	18.44	72
Oseberg	141.4	144	1988	30	23.59	100
Sleipner	163.4	55	1993	30	16.92	81
Snorre	133.1	103	1992	20	14.98	325
Tordis	121.5	30	1994	10	19.98	200
Troll Olje	384.0	51	1995	20	14.43	330
Ula	177.9	21	1986	30	37.89	70
Veslefrikk	161.0	29	1989	20	18.44	175
Tommeliten gamma	244.6	18	1988	10	14.98	72
Frøy	800.0	19	1995	10	19.41	120
Lille-Frigg	1114.3	3	1994	10	19.98	110
Ekofisk	142.0	21	1975	30	6.1	70

Table A.2 below presents the panel data used for the regression of equations (3) and (4). Sources of data are the following: Production: Official Statistics of Norway (quarterly statistics on the petroleum sector), Reserves and year of production start: Ministry of Oil and Energy (fact sheet), Number of service suppliers and Norwegian market share: The Ministry of Oil and Energy (the PI database).

Table A.2 Panel data, the production phase

Field	Year	Produksjon (mtoe)	Reserves/years since production start	Number of services suppliers	Norwegian market share	Time since production start
Ekofisk	1983	24.6	42.3	15	0.84	13
	1984	22.1	39.3	15	0.97	14
	1985	20.2	36.7	64	0.73	15
	1986	15.6	34.4	76	0.90	16
	1987	14.6	32.3	46	0.80	17
	1988	17.1	30.5	103	0.90	18
	1989	18.6	28.9	46	0.87	19
	1990	18.3	27.5	46	0.87	20
	1991	18.2	26.2	47	0.84	21
	1992	19.1	25.0	52	0.90	22
	1993	19.0	23.9	57	0.57	23
Frigg	1983	9.9	14.6	10	0.72	7
	1984	11.5	12.8	10	0.62	8
	1985	11.6	11.4	14	0.64	9
	1986	10.8	10.2	16	0.84	10
	1987	10.2	9.3	14	0.83	11
	1988	9.2	8.5	9	0.75	12
	1989	9.0	7.9	13	0.80	13
	1990	6.3	7.3	7	1	14
	1991	5.7	6.8	9	0.74	15
	1992	4.9	6.4	10	0.84	16
	1993	3.9	6.0	7	0.80	17
	1994	2.6	5.7	2	0.74	18
Statfjord	1983	16.0	120.9	21	0.89	5
	1984	18.9	100.7	22	0.86	6
	1985	24.8	86.3	28	0.78	7
	1986	33.0	75.6	28	0.86	8
	1987	33.9	67.2	19	0.96	9
	1988	32.8	60.4	20	0.94	10
	1989	32.2	54.9	10	0.79	11
	1990	31.7	50.4	19	0.83	12
	1991	32.7	46.5	27	0.91	13
	1992	34.6	43.2	25	0.98	14
	1993	31.6	40.3	31	0.90	15
Valhall	1985	2.8	34.5	21	0.61	4
	1986	2.6	27.6	22	0.60	5
	1987	3.5	23.0	26	0.86	6
	1988	3.8	19.7	25	0.83	7
	1990	4.4	15.3	20	0.91	9
	1991	3.9	13.8	15	0.65	10
	1992	4.2	12.6	19	0.79	11
	1993	3.7	11.5	11	0.76	12
Oseberg	1988	1.0	148.2	15	0.91	3
	1989	11.6	111.2	11	0.71	4
	1990	14.8	88.9	13	0.78	5
	1991	18.0	74.1	10	0.69	6
	1992	22.5	63.5	10	0.69	7
	1993	24.5	55.6	9	0.99	8

Ula	1986	0.8	72.2	9	0.74	1
	1987	4.0	36.1	14	0.85	2
	1988	4.8	24.1	18	0.60	3
	1989	4.8	18.1	16	0.71	4
	1990	5.1	14.4	20	0.80	5
	1991	6.3	12.0	22	0.68	6
	1992	6.7	10.3	33	0.85	7
Gullfaks	1987	3.7	51.9	7	0.99	2
	1988	8.1	34.6	25	0.90	3
	1989	14.9	26.0	7	0.77	4
	1990	14.0	20.8	15	0.83	5
	1991	19.1	17.3	18	0.84	6
	1992	24.1	14.8	23	0.76	7
	1993	27.6	13.0	20	0.62	8
Gyda	1993	3.7	10.3	14	0.43	4
Snorre	1992	1.4	232.3	5	0.82	1
Draugen	1993	0.1	111.6	13	0.85	1

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Summary

The petroleum sector is a service-intensive industry. The quality, price and availability of services are therefore important for the productivity level in the petroleum sector. This paper analyses data on the Norwegian petroleum sector's purchases of services and estimates the contribution of service input to productivity. It is found that specialisation in the service sector, measured by the number of service suppliers in the market, contributes significantly to the level of productivity of capital equipment. Specialisation in services also contributes directly to productivity in oil and gas, but the results are significant only at a 10 per cent level. We argue that an open market for oil-related services is likely to improve productivity in the Norwegian petroleum sector.

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