Liberalization of trade in services and choice of technology in the Norwegian petroleum sector

Hildegunn Kyvik Nordås

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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 analyzes how intermediate inputs contribute to productivity in the Norwegian petroleum sector and discusses how technical progress and changes in the international trade regime affect productivity and vertical relations between oil companies and their suppliers. It is shown that in a small market, tailor-made inputs and close vertical relations between the oil companies and their suppliers are the preferred and most cost-effective technology. As the market expands, the relative cost of tailor-made inputs increases, and at one critical point becomes less cost-effective than standardized inputs. A policy implication of the analysis is that the NORSOK policy of enhancing standardization needs to be complemented with a more open market in order to achieve its objectives. The analysis is particularly relevant for oil-related producer services, since this is the market for intermediate inputs that is the least open.

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1 Introduction

The Norwegian supply industry has a larger market share on the Norwegian continental shelf than what is common in other oil-producing areas. The Norwegian market share is particularly large for oil-related services, averaging about 80 percent for engineering services and non-maritime services in the mid 1990s.[1] Such services are very important for the total costs of production in the petroleum sector, since they provide the design and planning of the production technology. The Norwegian petroleum industry also has a cost problem. In this paper we explore whether there is a relation between these two observations and how the vertical relations between oil companies, contractors and sub-contractors are likely to develop as the markets are liberalized.

Widespread use of tailor-made technology for a particular oil field is believed to have contributed to the relatively high cost level on the Norwegian continental shelf. After the oil price collapse in 1986, there was an urgent need to bring costs down. A joint effort between the oil companies, the supplier industry and the authorities was initiated (the NORSOK project).[2] One important element in the NORSOK process is to standardize inputs and production processes in order to reduce costs. The NORSOK process notwithstanding, it appears that tailor-made technological solutions are still widespread in the industry.

The purpose of this paper is to analyze under which conditions a profit-maximizing oil company will choose to purchase standardized inputs and apply standardized

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[1] Non-maritime services are services provided from rigs or onshore. Source: The PI database from the Norwegian Ministry of Oil and Energy.

[2] A similar project, the CRINE project was introduced to the British petroleum and offshore industry.

production processes and under which circumstances it prefers tailor-made technology. Our working hypothesis is that there is a trade-off between the tailoring of inputs on the one hand and diversity of inputs on the other hand. Thus, if the oil-company decides to contract a supplier to produce a specially designed input, it foregoes the opportunity to choose between a number of suppliers that compete in quality and price in an open market.

We develop a partial equilibrium model for the market for oil-related intermediate inputs that captures the trade-off between specificity and variety of inputs. In the following we use the term "specificity" in the meaning that an input is specially designed for a particular purpose, e.g. as an input in the construction of a particular oil platform or as an input to the extraction of oil and gas from a particular oil field. The design of specific inputs is seen as investments or up-front fixed costs in the production of such inputs.

A high degree of diversity represents the case when production of inputs is characterized by a high degree of division of labor such that there is a large number of producers of differentiated components. Standard features of models with differentiated intermediate inputs are that productivity increases with the number of differentiated inputs, and that the extent of the market determines the number of differentiated inputs. The significance of the extent of the market arises from the assumption that there are fixed costs related to developing a new variety.

We introduce specificity as an alternative source of productivity improvement into a production function with differentiated intermediate inputs. Figure 1 below shows an intuitive illustration of what drives the model and the results.

Figure 1a

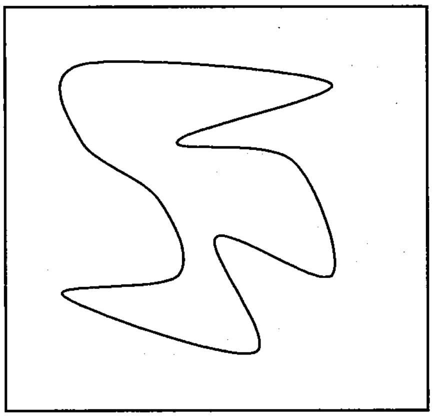

Figure 1b

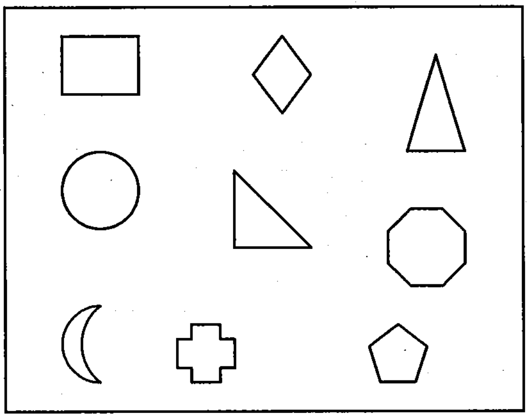

Figure 1a represents the complex offshore oil extraction technology. Figure 1b represents the variety of standardized intermediate inputs available in the market. Think of the extraction technology as the process of combining the available inputs in such a way that they fit into figure 1a. The better they fit without overlapping or extending beyond the borders of the figure, the higher the productivity and the lower the cost of the technology. Clearly, the greater the variety of inputs, the easier it is to find a combination that fills the complex figure 1a. This illustrates our main finding in the paper. If the market is small and accommodates only a few suppliers of differentiated inputs, the oil companies (or their major contractors) will ask the suppliers to bend and shape the inputs in order to get a better fit. This is what we model as investment in specificity. If the market is large and accommodates a large number of producers of differentiated inputs on the other hand, the oil companies/the contractors will purchase the standardized inputs. The ranking of alternative technologies according cost will be shown to be as follows:

1. Large market, standardized inputs (lowest cost);
2. Small market, specific inputs;
3. Small market, standardized inputs.

The size of the market for oil-related inputs in Norway is determined by three factors. First, the volume of demand from the local petroleum industry constitutes the most important market for Norwegian oil-related suppliers. Second, market access to other oil-producing countries' markets is important. The most relevant markets so far have been the British petroleum sector and the Gulf of Mexico. However, other areas such as Azerbaijan, Venezuela, Angola and Nigeria have recently become important after the Norwegian oil companies have entered these markets. Third, the market for oil-related inputs is determined by how oil-specific the inputs are. In other words, to what extent oil-related inputs can be sold to customers outside the petroleum sector. In this paper we explore the impact of expanding the market through internationalization of the Norwegian offshore industry. Internalization implies better access to markets outside the Norwegian sector and a more open Norwegian offshore industry. On the basis of the ranking of technologies above, we argue that the NORSOK process needs to be accompanied by a more open market, for example through market integration between the Norwegian and British petroleum sectors and a general liberalization of trade in oil-related inputs, particularly oil-related services, in order to achieve its objectives.

The rest of the paper is organized as follows. Section 2 reviews previous research. A model of the market for differentiated inputs is developed in section 3. The model is used for analyzing the optimal choice of specificity and the cost of producing equipment for the petroleum sector under various assumptions on the structure of the market. Section 4 presents some crude empirical evidence of the impact of integrating the Norwegian and the British North Sea petroleum sectors. Section 5 concludes.

2 Relations to previous research

The paper builds on the theory of productivity improvement through the improvement of the quality of intermediate inputs and the theory of productivity improvement through the expansion of the variety of intermediate inputs. (see for example Grossman and Helpman 1991). The latter theory has been interpreted as productivity growth through increased division of labor. The first author that was able to combine these two dimensions of productivity growth was Alwyn Young (1998). He was able to endogenize the choice between whether to invest in quality improvements or new varieties. His model was developed in order to resolve a major problem with endogenous growth models, namely that they predict that large markets grow faster than small markets, which is contrary to empirical evidence.[3] We build on a simplified static version of Young's idea of analyzing the trade-off between quality and diversity, but in our case the quality of an input is defined as how well the input fits into the production technology of a particular user.[4]

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[3] See for example Jones (1995).

[4] This reinterpretation leads us to the opposite conclusion of Young's paper. He argues that investment in diversity will fail to sustain growth because there are not sufficient intertemporal technology spillovers from such investments, while quality improvements do yield sustained growth due to intertemporal technology spillovers. We have no time dimension in our model, but since our quality concept relates to a particular user of the input in question, this by itself reduces the scope for

The analysis of specific investments in quality is best known from the industrial organization literature. This literature focuses on transaction costs related to such investments and sees the firm as an institution that economies on transaction costs. In contrast, our approach is production theory, and we present the firm by a production technology.[5] If the producers of intermediate inputs design inputs such that they fit into figure 1a exactly, this increases the value of the input to the buyer. We assume that the resulting changed properties of the input, compared to the standard inputs illustrated by figure 1b, are both observable and verifiable. Thus, we abstract from transaction costs and hold-up problems related to asset specificity and incomplete contracts.[6]

3 The Model

The NORSOK process relates as much to the design and construction of production equipment for oil and gas extraction as the operation of oil and gas extraction itself. This is because off-shore oil extraction is subject to significant economies of scale due to high up-front investment costs and relatively low marginal costs. In addition, the production technology is largely embodied in the production equipment and therefore to a large extent locked in for the duration of the equipment. It has therefore been important to reduce these up-front investment costs.

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technology spillovers, and diversity is actually more effective in improving productivity and reducing costs.

[5] See for example Riordan and Williamson (1985), Williamson (1985) and Baker, Gibbons and Murphy (1997) for a discussion of transaction-specific investment and transaction costs.

[6] A number of disputes over who should pay for cost overruns in the production of offshore equipment suggests that an interesting extension of our model is to incorporate transaction costs. In this paper, however, we wish to focus sharply on the technology choice between tailor-made technology and standardized technology focusing on the production technology. This is because the policy measures that have been introduced in order to reduce costs have almost exclusively been directed towards industrial relations, disregarding the importance of the extent of the market for the choice of technology.

The production function in the model developed in this section can be interpreted as the technology for exploration and development of an oil field. It can alternatively be interpreted as the extraction technology for petroleum, but since the exploration and development phases are of such crucial importance for extraction costs and particularly the development phase has been the major target of the NORSOK process, we focus on the former interpretation here.

3.1 Technology

The oil company enters a fixed price contract with a contractor who designs the equipment and the extraction technology on the basis of previous experience and the characteristics of the reservoir to be developed.[7] Next, the contractor constructs the equipment. This is done by means of the input of workers who use physical capital in order to assemble and install a large number of components. Differentiated producer services such as seismic shooting and analysis of seismic data, technology design, process engineering, planning, testing and coordination are crucial inputs before, during and after the construction process. Figure 2 illustrates the vertical relations between oil company, contractor and subcontractors.

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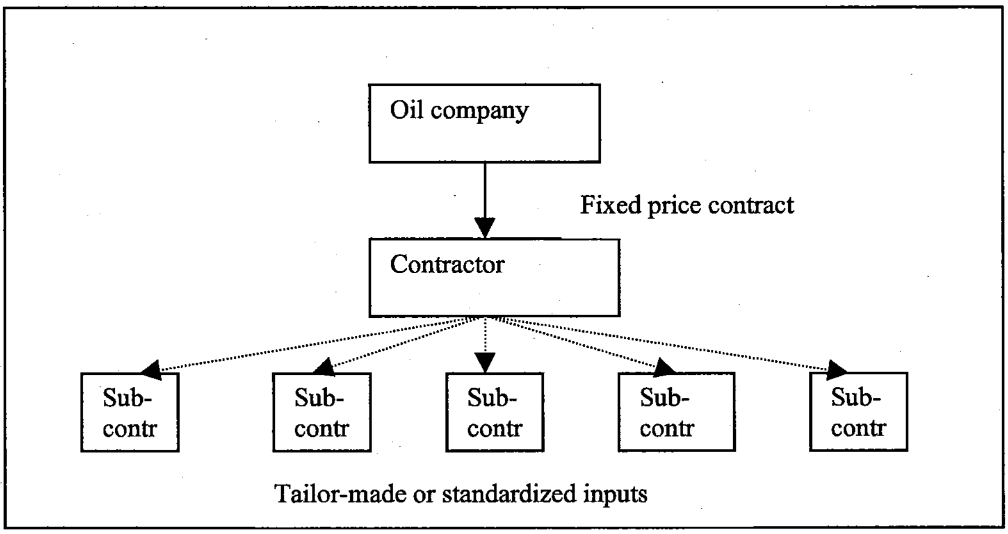
[7] A common contract type during the 1990s have been the EPC contracts (Engineering, Procurement and Construction). It is not a pure fixed price contract since cost overruns are partly born by the oil company. However, since the oil company in principle only covers cost overruns due to additional

Figure 2



The design and construction of the production equipment and technology for an oil field can be represented by the following production function:

$$Y = f(K, L, \sum_i \sum_j x_{ij}) \qquad (1)$$

Where Y is output, which we for simplicity think of as the production equipment which embodies the extraction technology for the oil field. K is capital, L is labor and there are *i* categories of intermediate inputs, each containing a number of differentiated inputs. Thus, the categories represent pipes, engineering services, maritime services, etc. We make the reasonable assumption that the production function is additively separable in the primary inputs and the intermediate inputs, such that it can be presented by a Leontief function between a (K, L) aggregate and the intermediate aggregate. Furthermore, we assume that the intermediate aggregate consists of a Leontief function of *i* categories of inputs. Finally each category of intermediate inputs consists of a CES aggregate of n_i differentiated goods or services

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work and extensions required by the oil company, the EPC can be seen as a good proxy to a fixed price with an elasticity of substitution assumed to be larger than unity. Thus, engineering services can not be substituted for pumps or pipes, but there exist a variety of engineering services that can substitute for each other. This assumption allows us to focus on one category of intermediate inputs at the time while keeping capital, labor and the other categories of inputs constant.

3.2 *Market conditions*

We assume that there exists a "monopolistically competitive fringe" in each input category. Thus, there exists a fringe of for example engineering service firms that offer their standard services as illustrated in figure 1b on a spot market. The number of such firms is sufficiently large to ensure that each firm breaks even, but earns no excess profits. The contractor can choose between purchasing inputs on this spot market or enter into contracts with the suppliers in order to get inputs designed for their particular needs.[8] In that case the supplier has to make an investment that will have no value to other potential customers. Therefore, specific inputs will be more expensive than standard inputs. It can easily be shown that under such market conditions the contractor will choose the same level of specificity for all inputs within a category. This also makes sense intuitively since the components in a production process usually need to be technologically compatible. The service input aggregate X_i can be represented by the function:

$$X = \left[\sum_{1}^{n} (q_j s_j)^{\alpha} \right]^{\frac{1}{\alpha}} \qquad = n^{1/\alpha} qs \qquad (2)$$

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contract.

We omit subscript i for convenience and refer to input category i in the rest of this section if not otherwise stated. Specific quality is represented by q while s represents quantity of the producer service. When $q = 1$ the quality is the standard quality illustrated in figure 1b while $q > 1$ represents specific design for the contractor. No other firms but the contractor are willing to pay a premium over and above the price for the standardized service for quality q.

Subcontractors incur a fixed cost f in order to set up a firm and design an input.[9] In addition, they may choose to make specific investments specified in a contract with the contractor. The subcontractor has the following cost function:

$$C_s = f + g(q) + \gamma s \qquad g' > 0,\ g(1) = 0 \qquad (3)$$

where γ is marginal cost of producing the service. It is well known that the monopolistic competitive subcontractors fetch a price $p = \gamma\alpha^{-1}$, and thus a mark-up over marginal cost related to the elasticity of substitution between any two inputs in the CES aggregate. The cost function facing the contractor for this particular input category if he chooses the tailor-made technology can then be represented as:

$$C_x = \left[\sum_{1}^{n}\left(p_i^{1-\varepsilon} q_i^{\varepsilon-1}\right)\right]^{\frac{1}{1-\varepsilon}} X + n\lambda q \qquad (4)$$

---

[8] The investment corresponds to bending and shaping the standard services represented by figure 1b in order to make them fit exactly into figure 1a.

[9] We use the term subcontractor on firms supplying the major contractor with inputs in the design and production of offshore equipment, whether or not the firm in question enters a formal long-term contract for tailoring inputs or the firm sells standardized inputs in a spot market.

where $\varepsilon = 1/(1-\alpha)$ and represents the elasticity of substitution between any two products, λ represents the per unit cost of specificity paid by the contractor. If he chooses the off-the-shelf technology the cost function is the first term of equation (4) only. By Shephard's lemma the contractor's demand for each service, given the quality is:

$$s_i = \frac{p_i^{-\varepsilon} q_i^{\varepsilon-1}}{\left[\sum_1^n p_i^{1-\varepsilon} q_i^{\varepsilon-1}\right]^{\frac{1}{\alpha}}} \mathrm{X} \tag{5}$$

In order to keep the analysis tractable, we will in the following assume that the contractor and the supplier of tailor-made inputs enter a contract where the contractor pays the subcontractor for his specific investment; e.g. $\lambda = g(q)$. We can then derive the unique size of the service firm by combining the cost function (3) and the revenue of the service firm, which is $s\gamma\alpha^{-1} + g(q)$. The unique size of the producer service firm is hence:

$$s_i = \frac{\alpha f}{\gamma(1-\alpha)} \tag{6}$$

We will now derive the cost functions related to category *i* of inputs and the optimal choice of specificity for differentiated inputs of category *i*. Since all inputs enter the production function and the cost function symmetrically, we can present the cost functions as:

$$C_x = n^{1/(1-\varepsilon)} p q^{-1} X + n\lambda q$$

$$\frac{\delta C_x}{\delta n} < 0 \text{ when } \alpha\lambda q^2(\varepsilon-1)\gamma^{-1} n^{\varepsilon/(\alpha-1)} < X \text{, and } \frac{\delta^2 C_x}{\delta n^2} > 0$$

Note that costs are a declining function of the number of inputs employed when X is sufficiently large, but costs decline with the number of inputs at a diminishing rate. This reflects gains from division of labor, while at the same time there is congestion as the number of inputs grows large. The number of subcontractor firms can be found by the market clearing condition for each input, e.g. equating supply (equation (6)) and demand (equation (5)). This yields:

$$n^{\varepsilon/(\varepsilon-1)} = \frac{\gamma(1-\alpha)}{\alpha f q} X \qquad (7)$$

Plugging (7) into the cost functions for the differentiated input, we get

$$C_x = \left(\frac{\gamma(1-\alpha)}{\alpha f q} X\right)^{-1/\varepsilon} \frac{p}{q} X + \left(\frac{\gamma(1-\alpha)}{\alpha f q} X\right)^{(\varepsilon-1)/\varepsilon} \lambda q$$

We now turn to the analysis of the optimal choice of specificity and discuss the trade-off between specificity and specialization.

3.3 Specificity versus variety

In this section we start by analyzing the case when specificity is a continuous and linear function of the investment made in the input. In many cases, however, there appears to be a threshold level of investment below which the parties are not willing to enter into a contract. This can for example be due to costs of collecting the necessary information for evaluating the options available, or indivisibility in investments needed to achieve quality $\overline{q}$. We therefore analyze an alternative setting where the degree of specificity of the input can take on two values, $q = 1$, which implies no investment, or q is equal to a constant higher than the optimal quality chosen with a linear investment function.

3.3.1 Continuous demand for specific quality

The optimal choice of specificity is found by maximizing the contractor's profit function with respect to q: max $\pi = R(Y) - C_x$ where R(Y) is the revenue function, assumed to be fixed by the contract with the oil company. The profit maximization problem yields the following optimal choice of specificity:

$$\frac{\delta\pi}{\delta q} = 0 \rightarrow q = \frac{\varepsilon(\varepsilon - 1)f}{\lambda} \qquad (8)$$

There is in other words a unique degree of specificity that maximizes the contractor's profit, given the rather strong assumptions made on contractual relations and specificity. The optimal level of specificity increases with the elasticity of substitution between differentiated inputs and with the degree of economies of scale in the production of inputs (*f*), and declines with the cost of specificity. Thus, if the elasticity of substitution between differentiated inputs is high, diversity is less important and specificity is more important than what is the case when the elasticity of substitution is low. Investment in specific quality is thus more valuable to the contractor with a high elasticity of substitution. Also, if the cost of developing a differentiated service (*f*) is high, there is room for fewer varieties as can be seen from equation (7), and the desired level of specificity is higher (as illustrated by figure 1a and 1b). A high degree of specificity, as observed in the Norwegian offshore sector can thus be explained if there are economies of scale in the supply industry and a high degree of substitutability among the firms' products.

3.3.2 Exogenous level of specific quality

A continuous demand function for specificity is probably not always realistic. It is probably the case that there is a threshold quality level that the contractor is willing to enter into a contract to secure. In the following we will assume that this threshold is exogenously given at $\overline{q} > \varepsilon(\varepsilon-1)f/\lambda$, and that the contractor can choose between entering into a contract with all his suppliers providing the quality $q = \overline{q}$ or purchase all inputs on the spot market where the quality of inputs is $q = 1$. Given symmetry, demand for each input in the two alternative technology cases is given as:

$$s^a = n^{-1/\alpha}\overline{q}^{-1}X \quad \text{and} \quad s^s = n^{-1/\alpha}X \qquad (9)$$

for the specific input and the spot market input respectively. The unique size of the subcontractor firm is the same as before and given by equation (6). We can therefore find how many firms can be accommodated in each of the two cases:

$$n_a = \left(\frac{\gamma(1-\alpha)}{\alpha f\overline{q}}X\right)^{\alpha} \quad \text{and} \quad n_s = \left(\frac{\gamma(1-\alpha)}{\alpha f}X\right)^{\alpha} \qquad (10)$$

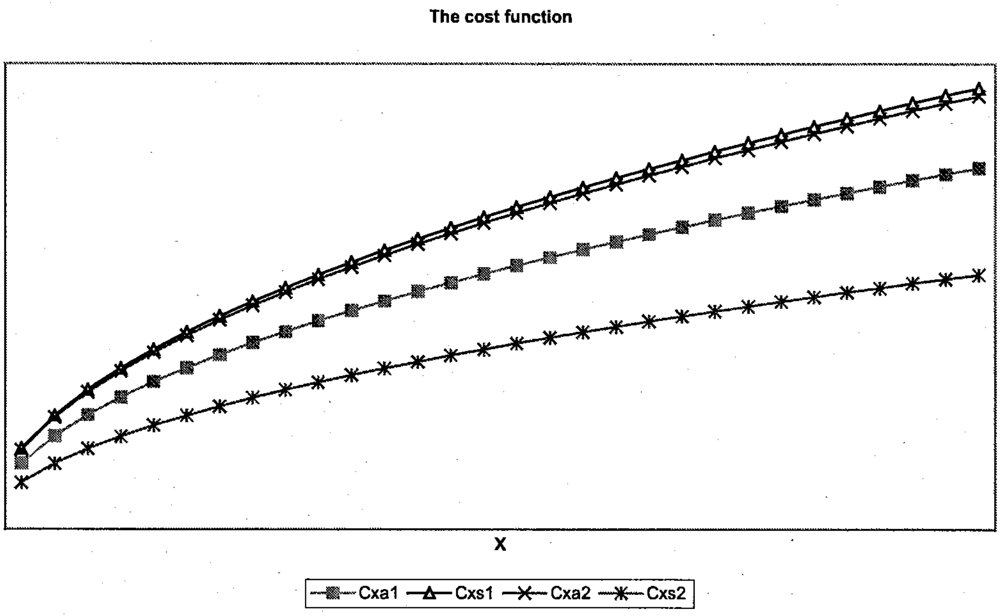
Clearly, there is room for more subcontractor firms when the technology provided by the spot market is chosen. Plugging this into the cost functions of each technology yields:

$$C_x^a = \left[\left(\frac{\gamma(1-\alpha)}{\alpha f \bar{q}} \right)^{-1/\varepsilon} \frac{\gamma}{\alpha \bar{q}} + \left(\frac{\gamma(1-\alpha)}{\alpha f \bar{q}} \right)^{(\varepsilon-1)/\varepsilon} \lambda \bar{q} \right] X^{(\varepsilon-1)/\varepsilon} \tag{11a}$$

$$C_x^s = \left(\frac{\gamma(1-\alpha)}{\alpha f} \right)^{-1/\varepsilon} \frac{\gamma}{\alpha} X^{(\varepsilon-1)/\varepsilon} \tag{11b}$$

Comparing the two cost functions it is clear that the tailor-made technology is the most cost-efficient when $\bar{q}^{(1-\varepsilon)/\varepsilon}(1+(1-\alpha)\lambda\bar{q}/f)<1$. The larger is $\bar{q}$ and f and the smaller is λ, the larger the cost advantage of the tailor-made technology. As long as the contractor is the sole customer of the subcontractors, which is implicitly assumed here, the relative cost of the two technologies (off-the-shelf and tailor-made) is independent of the size of total demand from the contractor, X. Figure 3 below depicts the two cost functions for two different degrees of scale economies.

Figure 3



Cxa1 and Cxs1 depict the specific and the off-the-shelf technology respectively for a high level of fixed costs *f*, while Cxa2 and Cxs2 depict the two technologies with a relatively low level of economies of scale.[10] In the first case the tailor-made technology is the most cost efficient, while in the second case the off-the-shelf technology is the most cost effective. With the parameter values chosen here, the tailor-made technology with a low degree of scale economies is about as expensive as the standardized technology when economies of scale are more important. Thus, widespread use of tailor-made technology may be cost effective relative to standardization if economies of scale are important in the supply industry.

3.4 An alternative market

In sections 3.1 – 3.3 we have focused on the choice of specific quality, assuming that the contractor is the only customer of the subcontractors. In this section we will explore how the choice of specificity changes if our contractor is one among several potential customers. Thus, the contractor may choose to enter into a contract with a subset of the total number of supply firms that operate in the relevant markets. The number of firms that can break even servicing the contractor is still determined by equation (10). We denote the size of the alternative market Z. This constitutes the monopolistically competitive fringe and can accommodate $n_z = \left(\gamma(1-\alpha)Z/\alpha f\right)^{\alpha}$ firms, assuming that the elasticity of substitution between the varieties in the input aggregate is the same in the alternative market as it is for the contractor. This may be a strong assumption, but if we allow differences in the elasticity of substitution, determining the price of the input becomes more complicated without adding important additional insights, we believe.

With this, perhaps more realistic presentation of the market for intermediate inputs, the off-the-shelf technology cost function is derived by inserting the expression for n_z in the cost function, which yields:

$$C_x^z = \left(\frac{\gamma(1-\alpha)}{\alpha f}\right)^{-1/\varepsilon} Z^{-1/\varepsilon}\frac{\gamma}{\alpha}X$$

The relative costs of the two technologies is now given by:

$$\frac{C_x^a}{C_x^z} = \left(\frac{X}{Z}\right)^{-1/\varepsilon}\bar{q}^{(1-\varepsilon)/\varepsilon}\left(1+\frac{1-\alpha}{f}\lambda\bar{q}\right) \tag{12}$$

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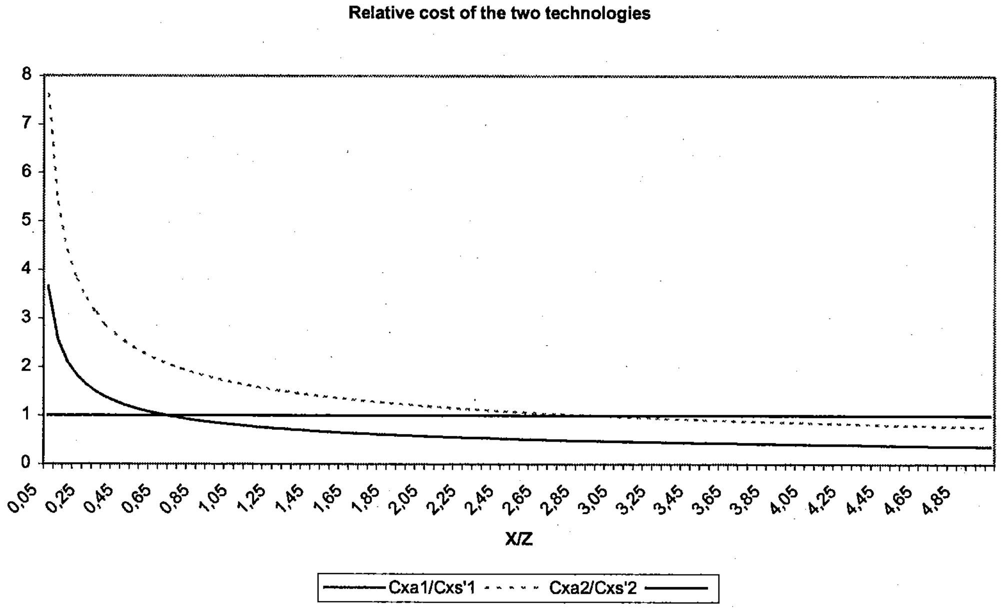
[10] The figure is drawn for λ=4, α= 0.5 γ =1 and q =7. f = 12 for the first set of cost functions while f = 4 for the second set.

When an alternative market for differentiated intermediate inputs outside the relationship with the contractor is introduced, the relative size of the two markets matters for which technology is the most cost effective. Figure 4 depicts equation (12) for the same parameter values as in figure 3. The vertical axis shows the relative cost while the horizontal axis measures relative size of the two markets; e.g. X/Z. We have also included the unity relative cost line, which shows the switch point in technology choice for a profit-maximizing contractor.

Figure 4



If we start at the right-hand end of the chart, we see that when the contractor constitutes a very large share of the total market for the relevant category of intermediate inputs, and thus X/Z is large, the tailor-made or specific technology is the most cost efficient; e.g. $C_x^a / C_x^{s'} < 1$. As we move to the left and the relative size of the alternative market increases, the cost advantage of the tailor-made technology declines, and at one point the relative cost curve crosses the unity line and the off-the-shelf technology becomes the most cost effective. Notice also that the relative cost curve shifts inwards as the economies of scale increases in the supply sector. Thus, the higher is f the further to the left is the switch point where the off-the-shelf technology becomes the most cost effective from the contractor's point of view. The model thus shows that given a large enough market for the supply sector, the market offers enough diversity for the off-shore contractor to replace specific with off-the shelf inputs.[11]

4 Empirical applications of the model

We will interpret the contractor to represent the offshore sector as a whole. In practice this means three dominant firms which are Aker Maritime, Kværner and Umoe. As mentioned in the introduction, engineering services and non-maritime services have a very high market share on the Norwegian market and these services, particularly the former, are crucial inputs determining the cost level in Norwegian oil production. Engineering services are broadly defined as technology design, project management, process management, pre- and detailed engineering and concept evaluation to name the most important. The variable X in the model thus represents the Norwegian offshore sector's demand for engineering services.

The alternative market may have several interpretations. One interesting option is to analyze the linkages from the offshore sector to other sectors of the economy. Z should then represent all sectors that use engineering services as intermediate inputs. Another interesting option is to look at international trade in oil-related engineering services. Z could then represent the entire North Sea offshore market or the world

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[11] The diversity of these inputs in turn allows him to customize his own technology if he so whishes by

offshore market. In this section we provide some preliminary empirical analysis of the impact of expanding the alternative market through international trade in services.

Let us start with a look at the diversity of engineering services supplying the Norwegian offshore market. During the period 1980 – 1994 about 520 different firms provided engineering services during design and construction for Norwegian offshore production platforms and equipment. Of these 320 were fully owned Norwegian companies, 54 were Norwegian affiliates of multinational engineering firms and 146 were foreign firms not incorporated in Norway.[12] These figures suggest that the diversity in the engineering service sector is sufficient to support the application of a Dixit-Stiglitz type production function as in equation (2).

Investments in the British sector and the Norwegian sectors of the North Sea were about £4.4 bill. and NOK 35 bill. respectively in 1997 (DTI, UK 1999, Official Statistics of Norway 1999). Hence, investment in the British sector was about 1.45 times higher than in the Norwegian sector in 1997. The ratio X/Z between the Norwegian sector and the entire North Sea should thus be about 0.4. This is well within the range where the standardized technology is the less expensive according to figure 4. In other words, the model suggests that integration of the two markets for oil-related engineering service inputs would induce the change in technology that the NORSOK process has only partly achieved.

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mixing or combining the inputs in order to make them fit into figure 1a.

[12] Source: The PI database from the Ministry of Oil and Energy. The figures represent a count of all the different firms that have entered a contract with an oil company for delivery of engineering services during the planning and construction of oil platforms. We have not adjusted for mergers and acquisitions in the industry during the period in question.

5 Summary and conclusions

In this paper we have provided a framework for analyzing the trade-off between productivity improvement through improved quality versus a higher degree of specialization when quality is specific to a particular customer, applied to the Norwegian offshore industry. The offshore industry has had a cost problem and it has been suggested that the problem is rooted in too much field-specific technology. A higher degree of standardization has been suggested as a remedy for the cost problem, but in spite of joint efforts to this effect, the results have not been as hoped for.

Based on the fact that the offshore industry produces very complex production equipment which entails thousands of components and service inputs, we have modeled the sector as an assembly of intermediate, differentiated inputs. Furthermore, we have introduced a quality-parameter assumed to be specific to the investment project. It turns out that when there is a small market for the relevant differentiated inputs, the cost-minimizing contractor will choose the tailor-made technology. This is because there is not sufficient scope for specialization to outweigh the productivity improvement provided by the tailor-made input. Nevertheless, the cost level may be high compared to other oil-producing areas that may have a sufficiently large market to apply the off-the-shelf technology. The results from this analysis suggest that the switch point for introducing off-the-shelf technology for cost-minimizing offshore companies can be obtained in Norway if the Norwegian and the British North Sea sectors were more integrated, or if Norwegian supply firms became more export-oriented.

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