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Decommissioning of petroleum installations—major policy issues

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Abstract

Following the Brent Spar controversy, the OSPAR countries reached a unanimous agreement in 1998 for the future rules for disposal of petroleum installations. The vast majority of existing offshore installations will be re-used or returned to shore for recycling or disposal. For installations where there is no generic solution, one should take a case-by-case approach. We provide a survey of international economic and regulatory issues pertaining to disposal of petroleum installations, and provide specific examples by analysing the Norwegian decommissioning policy. Implications of disposal decisions for the fishing industry, a central stakeholder, are analysed.

Keywords: decommissioning; petroleum installations; externalities

1. Introduction

Disposal of obsolete offshore petroleum installations is a relatively new issue involving tens of billions of dollars globally.[1] Powerful players—multinational oil companies, environmental organisations and governments—all have high stakes here. A maj or point of dispute is the magnitude of social costs in terms of externalities to other users of the marine environment. The issue of petroleum installation decommissioning also raises important questions about, first, the public's willingness to pay for removal, and, second, the reputation effects for oil companies associated with different disposal decisions.

Brent Spar is the most recent case that has highlighted the public's concern about the disposal of oil installa-tions and the potential importance of reputation effects. The Brent Spar was taken out of operation in 1991 after some 15 years of service in the Brent Field in the northern North Sea. A very large floating oil storage and loading buoy the Spar, had stored oil from the Brent 'A' platform and acted as a tanker loading facility for the whole of the Brent Field. Studies by several independent companies established that deepwater disposal of the Spar at a site in the deep Northern Atlantic was the so-called 'Best Practicable Environmental Option' (BPEO). It was concluded that deep-water disposal would have negligible impact on the marine environment, which was confirmed by independent scientists. The UK Government approved this original plan in February 1995.

During the summer of 1995, a public protest arose in many countries against the planned deepwater disposal of the Spar installation—strongly supported by environmental organisations. Reputational considerations lead Shell to abandon deepwater disposal, and instead dismantle the installation on land. The new decision was approved by the UK government. Disposal costs increased from an estimated 38.5 million USD for a deepwater disposal to a final total of 71.4 million for the onshore dismantling, according to Shell (Lode, 1999). This gives an indication of Shell's valuation of the reputation effects.

In the process of developing a decommissioning plan, the oil companies use independent consultants and contractors to carry out environmental assessments, safety studies and cost analyses.[2] These are

[1] Disposal is defined as the process and/or agreement which brings an installation to its final location(s), where it is re-used, re-cycled or deposited (Anon., 1999, p. 215). *Decommissioning* is defined as the activities related to bringing a platform from an operating condition to a cold, hydrocarbon free condition (but does not include activities related to removal or other methods of disposal).

[2] Shell UK requested the international certification, classification and advisory body *Det Norske Veritas* (DNV), to perform a comparative assessment of the proposed options for disposal of Brent Spar (DNV Report No. 970911-0007). The scope of work covered technical feasibility, safety assessment, environmental assessment and price verification.

predominantly technical reports, undertaken by engineers, and they are generally not available to the public. In spite of the interesting policy issues and the large sums involved, decommissioning of petroleum installations seems to have been given scant attention by researchers of economics. We give an overview of the most important economic topics related to decommissioning and disposal, illustrated by recent Norwegian case material.

2. International decommissioning issues

There are more than 6500 offshore installations worldwide, with an estimated overall removal cost of 20 billion USD. There is a great variety of installations, each designed for a particular set of conditions: ranging from fixed shallow-water structures in 30 m of water to tension leg platforms in 900 m of water. Some 490 installations (excluding subsea facilities) are located in the North Sea and the North East Atlantic. The majority of platforms, around two-thirds, standing in less than 75 m of water or weighing less than 4000 tonnes, are referred to as small structures, although they can still be the size of the Houses of Parliament. The remaining platforms, mainly in Norway and the UK, comprise 112 large steel structures—which may be as high as the Eiffel Tower and have a footprint the size of a football field—and 28 concrete gravity base structures. In addition, there are some 26 floating installations. Over the next 10–20 years, an average of 15–25 installations are expected to be abandoned annually in Europe. This represents, amongst other materials, 150,000–200,000 tonnes of steel per year. The continental shelf bordering the states of the European Community and Norway counts some 600 offshore oil and gas platforms, 400 subsea structures and 600 subsea wellheads.

A typical platform consists of the *topsides*, which contain the drilling, processing, utilities and accommodation facilities, and the supporting *substructure* or *jacket.* Steel j acketscan weigh up to 40,000 tonnes and are fixed to the seabed by steel piles. The topsides themselves can weigh up to 40,000 tonnes. Concrete gravity base structures are even larger, for example, Troll on the Norwegian continental shelf weighs some 700,000 tonnes, and sits on the seabed, stabilised by their own weight and penetration of the *skirt* into the seabed. In the absence of storing facilities, only the topsides of the platform are in contact with hydrocarbons and may contain limited amounts of potentially hazardous substances, whereas the substructure or jacket is generally clean steel or concrete.

Cost–benefit calculations are in this context needed for two types of decisions: (a) the choice of method of removal and disposal of installations, and (b) timing issues. As for (a), after the production is closed down, topsides are in most cases taken to shore for recycling. Interesting policy issues, therefore, mostly pertain to the various solutions for the substructure. The basic decommissioning options are as follows:

(i) Leave in place.
(ii) Partial removal, with alternatives:

(a) emplacement/toppling on site, (b) carry to shore for recycling or disposal as waste,
(c) deepwater disposal, (d) artificial reefs, and (e) re-use/other uses.

(iii) Total removal, with alternatives: (a) carry to shore for recycling or disposal as waste,
(b) deepwater disposal, (c) artificial reefs, and (d) re-use/other uses.

Artificial reefs mean using cleaned offshore platforms to create reefs for marine life. Early evidence indicates that such reefs enhance and protect existing marine habitats and create new habitats for marine animals and plants.[3] Artificial reefs have been developed in the US, Brunei, Japan, Cuba, Mexico, Australia, Malaysia and the Philippines.

The choice of decommissioning procedure is subject to stringent and extensive international regulations. Still, considerable discretion is left to national governments. In 1958, the Geneva Conference adopted a Convention on the continental shelf, requiring that an offshore installation being abandoned must be entirely removed. The 1982 UN Conference of the Law of the Sea introduced some exceptions, allowing some installations to be left in place as long as requirements linked to navigational safety, fisheries and environmental impact were met. The 1989 UN International Maritime Organisation (IMO) Guidelines for the Removal of Offshore Installations required that abandoned structures standing in less than 75 m of water and weighing less than 4000 tonnes in air, excluding the topsides, must be entirely removed.[4] Platforms exceeding those limits need to be cut off to allow 55 m of clearance between their highest point and the surface. The water depth limit will increase to 100 m for new platforms installed after 1 January 1998. Disposal at sea of offshore installations in the North Sea or North East Atlantic is regulated by the Oslo and Paris Conventions. These two conventions were merged into one (OSPAR) in 1997. Following the Brent Spar controversy, the OSPAR countries reached a unanimous agreement in 1998 for the future rules for disposal of petroleum installations.[5]

[3] See section four for a further discussion and references.

[4] In addition, there are national regulations, which reflect the circumstances of the different countries. Since the UK and Norway are the only countries to have installations in waters deeper than 75 m, only these two countries have developed detailed procedures and guidelines for offshore disposal. Abandonment plans have to be approved by government and the necessary licences obtained.

[5] OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations.

The vast majority of existing offshore installations will be re-used or returned to shore for recycling or disposal. Exceptions are made for certain installations or parts of installations in the event that an overall judgement in each case gives good reasons for sea disposal. For those installations where there is no generic solution, one should take a case-by-case approach, and considerable discretion rests with local governments.

Local discretion is considerable for timing issues. The problem of determining the optimal removal date can be considered as a cost minimisation problem (Amundsen, 1997). In determining optimal removal date, the oil companies have to trade off a number of factors. The costs of keeping the platform at sea after closing down of production are maintenance costs. From the perspective of the government, there are also external effects to consider, i.e., effects on fisheries and the environment. The benefits of deferral of decommissioning, however, may be considerable. These benefits take the form of real options gained by postponing the removal of installations: (1) there may be potential gains in the form of improved technology of removal, since this is a new industry that is at the very start of its learning curve, and (2) the installations may once again be used for extraction purposes in the event of recovery of new petroleum reservoirs in the vicinity of the platform or in the event that new technology makes it possible to use existing facilities in producing from more remote reservoirs.

Two issues that are not analysed thoroughly in this paper, but nevertheless deserve to be mentioned, since they seem to have some influence on both international legislation and disposal decisions, are the population's willingness to pay for a clean environment, a public good, and reputation effects stemming from decisions on disposal options.

Although few individuals may physically experience obsolete offshore oil installations, one should consider the possibility that the public may be willing to pay for their removal, even in the absence of environmental externalities in the form of pollution, etc. A significant proportion of the public probably desire that the oceans are kept close to their "natural" state. For example, many individuals do not like the thought of oceans devoid of mammals first-hand. Analogously, individuals may not like the idea of the ocean being used as a "graveyard" for large oil installations, however far these may be from the coast or sea travel lanes. Hence, as the public may be willing to pay for the existence of blue whales, it may also have a positive willingness to pay for the recycling of redundant offshore installations.

The negative existence value of offshore oil installations may be one of the elements influencing the reputation costs associated with decommissioning. Reputation is often viewed as a strategic resource for the individual holder, as a positive reputation may provide the holder with goodwill capital. If a country's—or company's—decommissioning policies lead to a reduction in goodwill, other countries' public opinion, special interest groups and governments may become less tolerant of its actions in other areas, and may even introduce direct reprisal actions in the form of public protests, boycotts or court actions. The Brent Spar and Exxon Valdez incidents are two cases where the oil companies involved seem to have perceived the reputation costs to be considerable and have been willing to incur extra costs to reduce these (SNF, 1998, Chapter 4).

3. Norwegian decommissioning policies

We now discuss decommissioning with reference to Norwegian case material. Publicly available government reports containing details on decommissioning in specific fields, make Norway a good research choice in terms of available data. The fact that Norway—having many of the largest extraction facilities in the world—represents a large fraction of global disposal costs, makes it an interesting country in its own right. There are also several reasons why the Norwegian case is of general relevance. In Norway there is a wide range of offshore petroleum fields that differ considerably with respect to water depths and design of extraction facilities. Thus, it offers diversity regarding technical complexity and costs associated with removal. Further-more, the fact that Norwegian authorities have a record of high environmental standards may imply that Norwegian case material may give indications as to future global developments in the decommissioning arena.

The Norwegian Parliament sanctioned the OSPAR Convention. However, there is a number of large installations on the Norwegian continental shelf for which decommissioning is not regulated directly by the Convention. Concrete installations and steel jackets with weight above 10,000 tonnes are exempted from the OSPAR ban on sea disposal. For concrete installations, the Norwegian government has full discretion, i.e., they may be fully or partly removed, left in place, toppled on site for use as artificial reef, or dumped elsewhere.[6] The Norwegian government also has partial discretion with respect to decommissioning of the six largest permanent steel installations on the Norwegian continental shelf,[7]

[6] See proposition from the Norwegian government, St. prp. no. 8, 1998–99.

[7] Two installations on the Ekofisk Field, two on the Oseberg field, and one on the Brage and Heimdal fields.

permanent steel installations on the Norwegian continental shelf i.e., the jacket may be left on the seabed but not dumped elsewhere.[8] After 9 February 1999, however, all new steel installations must be designed so that the total removal is feasible.

Characteristic features of the Norwegian continental shelf are great depths and large reservoirs, developed by large installations. Thus, the cost of decommissioning in the Norwegian sector is on an average considerably greater than in the rest of the world. There are approximately 6500 offshore oil and gas installations in the world, with an estimated overall removal cost of 20 billion USD. Decommissioning all of the Norwegian installations was in 1993 estimated to cost 7.5 billion USD, i.e., as much as 37.5 per cent of the estimated global costs.[9] Such estimates are highly uncertain, though. There is not much experience in this field; the first Norwegian decommissioning plan was issued in 1994. New technology and the development of a decommissioning industry are likely to bring down removal costs. Thus, an estimate from 1995 was 5.4 billion USD for a total removal of all installations, and 1.8 billion for a partial removal.[10] The total investments on the Norwegian continental shelf at that time, in comparison, were 100 billion USD. Nevertheless, adding the fact that the Norwegian government will carry most of the costs, and that the maj or part of these costs will come in a period when petroleum revenues are declining and the number of retirees is increasing, decommission-ing will be a considerable fiscal burden for Norway. By establishing a considerable petroleum fund, however, the Norwegian authorities should have the means to smooth out this effect.

The procedures for decommissioning decisions are as follows. The license owners, represented by the operator, develop a detailed decommissioning plan. The plan is to examine and evaluate different decommissioning options. It has a conclusion, which can be perceived as an application for the licensees preferred decommissioning option. Thereafter, the plan is submitted to the government and at the same time .circulated to a number of environmental and fisheries organisations for comments. The plan is then reviewed by the Ministry of Petroleum and Energy, which considers environmental, technical, economic and resource aspects. Furthermore, the ministry considers international obligations and the consequences for fisheries and shipping, and the comments of environmental and fisheries organisations. Typically, the recommendation from the Ministry to *Stortinget* (the Norwegian parliament), lies somewhere between the recommendations from the licensees and the environmental and fisheries organisations. The latter typically advocate a complete removal of all installations, whereas the former would often prefer some of the facilities to remain on the field or to be dumped. The Ministry would recommend only special facilities, such as pipelines, to remain ashore. In these recommendations to Stortinget, it is emphasised that each field is unique and that the recommendations are not intended to form a precedent. Existing Norwegian offshore petroleum installations are very heterogeneous with respect to factors influencing decommissioning, such as external effects and removal costs, calling for a separate evaluation of each case.

3.1. Two decommissioning cases: the Odin field and the Ekofisk field

In this section, we examine two decommissioning cases which can be said to represent two extremes with respect to the technical complexity and costs associated with removal of offshore oil installations, the Odin field and the Ekofisk field.

A maj or part of offshore installation removal costs are mobilising and demobilising costs for specialised vessels. These costs can be reduced if decommissioning can be combined with other tasks performed by the specialised vessels on the continental shelf. In addition, there are day rates to be paid for the vessels. If there is a long transport distance related to deepwater disposal, the savings compared to land disposal are not large.

In Norway, it is politically not perceived as an option to leave steel installations with the topside intact, or to topple it on site.[11] Furthermore, dumping of installations in international waters is not viewed as politically acceptable.

[8] Provided that there are 55 m of clear water over the remains to ensure safety of navigation.

[9] See report to the Norwegian government, NOU, 1993:25.

[10] See proposition from the Norwegian government, St. prp. no. 36, 1994–95.

[11] See proposition from the Norwegian government, St. prp. no. 8, 1998–99.

Once the expensive operation of lifting the topside off the jacket has been undertaken, it is optimal—also in economic terms—to take it on shore for re-circulation. The experience from decommissioning of the Odin field on the Norwegian continental shelf is that it is cheaper to take the topside on shore than to dump it. Part of the explanation is that by deepwater disposal the transportation costs would be similar to those of taking the installation ashore, and also it is much more costly to clean the facilities at sea. In addition, there is the question of future liability for dumped installations.

For the Odin field, the decommissioning study headed by Exxon, evaluated three different decommissioning options for the topside and the modules, as shown in Table 1.[12]

The licensees recommended alternative (a). This recommendation was supported by the Ministry as being the best solution in both economic and environmental terms. Similar calculations were made for the substructure, as shown in Table 2.

Table 1
Decommissioning options for topside and modules

Alternative	Estimated cost (Mill USD)
(a) Remove and take ashore for recycling	15.5
(b) Remove and dispose on deepwater	18.5
(c) Placed on seabed as artificial reef	20.4

Table 2
Decommissioning options for substructure

Alternative	Estimated cost (Mill USD)
(a) Remove and take ashore for recycling	12.9
(b) Remove and dispose on deepwater	21.5
(c) Placed on seabed as artificial reef	8.4

The licensees recommended alternative (c), in situ toppling of the jacket, as a pilot project for artificial reefs. A condition from the oil companies for choosing this solution was that the ownership and the liability of the remaining installation were transferred to the Norwegian government, without any compensation to the Norwegian state. As for environmental impact, recycling of steel (compared to production of new steel) would reduce emissions of CO_2 equivalents and NO_2 by 21,000 and 35 tonnes, respectively. The Ministry recommended alternative (a); the savings of 4.5 million USD were not considered enough to compensate for environmental effects and transferral of liability. It was not ruled out, however, that alternative (c) could be relevant for other fields.

The costs of removing and recycling the pipelines on the Odin field were estimated to be 8.7 billion USD. The licensees recommended the pipelines to be left on the seabed, after being properly cleaned. Having been used for the transport of gas, the pipeline would be free of heavy petroleum remainings. The Ministry postponed the decommissioning decision about the pipelines, pending environmental evaluations and evaluations and negotiations about where liability should be placed for installations that are left permanently on the seabed.

The Ministry's decommissioning recommendations for the Odin field were similar to those for Nordøst Frigg.[13] The operator, Elf petroleum, recommended dumping the monitoring station of 6000 tonnes, but was instructed to take it on shore for recycling. Pipelines remained on the seabed as possible negative environmental effects could not justify the considerable removal costs (11 million USD).

[12] See proposition from the Norwegian government, St. prp. no. 50, 1995–96.

[13] See the proposition from the Norwegian government, St. prp. no. 36, 1994–95.

The Ekofisk field represents a decommissioning case of a far greater scale than the Odin field. Phillips Petroleum, the operator of the Ekofisk field on the Norwegian continental shelf, has recently presented a two-stage decommission plan, with a total cost of 1.1 billion USD.[14] The Ekofisk field is located in the Norwegian sector of the central North Sea. There is a total of 34 installations, including flare stacks, at the Ekofisk and associated fields. Of these, 25 are main structures, amounting to 3.5 million m^3 of jacket volume. Approximately 25 local pipelines connect the installations in the Ekofisk area. These pipelines have a diameter varying from 200 to 750 mm. The majority of the pipelines are trenched, except for the free ends of 30–100 m near the platforms. Each installation has a safety zone with a radius of 500 m.

At the first stage of the Ekofisk decommission plan, the topsides of 15 installations with a total weight of 107,000 tonnes will be removed and taken on shore for recycling or re-use. This operation will begin in 2003 and the estimated costs are 0.7 billion USD. At the second stage, to be commenced in 2015, the substructures (steel jackets) of 14 installations with a total weight of 64,000 tonnes are to be removed at a total cost of 0.4 billion USD. These substructures have to be removed under the OSPAR convention, while an exception is made for a concrete substructure weighing 1.2 million tonnes which will be left in place. Phillips expects that new removal technologies will be introduced before 2015, thereby reducing the removal costs for the substructures.

Removal costs are of a very different order of magnitude in the case of the Odin field and the Ekofisk field. The experience from the Ekofisk field suggests that when removal costs are large, both government and oil companies prefer to defer. Since there are other fields with removal costs of a similar magnitude, one may raise the question whether we, over time, will see an accumulation of non-producing petroleum installations for which removal is deferred, until one reaches a point when the total accrued removal costs are too large to be carried by the society, with the effect that large parts of the installations are left standing at the abandoned fields indefinitely.

3.2. Tax treatment of decommissioning

Decommissioning raises some interesting tax ques-tions. As a background for this discussion we first present the general features of the Norwegian petroleum tax regime. The Norwegian petroleum tax system is based on the Norwegian rules for ordinary corporate tax, charged at 28 per cent of the corporate profit. Owing to resource rents, a special tax of 50 per cent has been added to this industry, implying a marginal corporate income tax of 78 per cent.[15] Licences are allocated by a discretionary licensing system, with no up-front payments by the companies. Statoil, a 100 per cent state-owned company, operates on the Norwegian continental shelf on a commercial basis. Through the State's Direct Financial Interest (SDFI), the Norwegian government is a passive stake-holder in many licences.[16] In addition, the Norwegian state owns 40 per cent of Norsk Hydro, a central actor on the Norwegian continental shelf.

As for tax treatment of decommissioning expenses, should (a) the oil companies be allowed appropriations in the tax accounts for future removal costs, or (b) should the actual removal costs be tax deductible?Neither is the case in the Norwegian Petroleum Tax Code. Instead, the state's share of the removal costs is paid directly to the oil companies at the time of removal. These levies are individually sanctioned by the Norwegian Parliament. The main rule for the state's share, estimated in each separate case, is the average effective corporate income tax rate the company has faced on the net incomes from the field. This system for tax treatment, which represents an equal tax treatment approach of all fields, is thus a cost-sharing rule that is mimicking the tax effect of scheme (a). If the oil company has been in a tax paying position in the entire period of operation, the state's share is approximately 78 per cent. For the decommissioning of 15 platforms at the Ekofisk field, starting in 2003, the state is to pay about two-thirds of the removal costs.[17] There are, however, exceptions to this cost sharing rule. In cases where the estimated state share is unreasonably low, the state's share can be increased, after application by the operator. For the Nordøst–Frigg field the state's share was increased from 39.7 to 50 per cent after application. Exxon applied for increasing the state's share to 68 per cent, up from 38.2 per cent according to scheme (a), and was granted 50 per cent.[18]

[14] See Anon (1999) and *Stavanger Aftenblad,* October 22, 1999.

[15] Although Norwegian petroleum taxation is mainly a profits tax, royalty is payable on oil production from fields approved for development before 1986, and recently a carbon tax has been imposed on petroleum that is burnt and on gas that is directly released. It has been decided, however, that the royalties will be phased out over a three-year period. Also, the CO_2-tax is likely to be reduced.

[16] For more details on the Norwegian petroleum tax system, see MPE (1998).

[17] *Stavanger Aftenblad*, October 22, 1999.

[18] See proposition from the Norwegian government, St. prp. no. 50, 1995–96.

In calculating the revised cost share, the government has taken into account the company's future tax position in Norway,[19] i.e., scheme (b) is applied. Thus, while the main rule is (a), rule (b) may be applied if the main rule is unreasonable.

Although. the tax treatment of decommissioning costs does not convey advantageous tax credits, it does seem to provide the oil companies with a higher probability of obtaining a tax deduction than is the case for other costs.

According to a proposition bill from the Norwegian government (Ot. prp. no. 33, 1985–86), there are several reasons why removal costs are given a special tax treatment. One objective is to avoid discrimination. With a traditional tax treatment, (b), a number of firms would not have had a full tax deduction, since at the time of removal they may not have had sufficient income generated in Norway to cover the costs. It is thus not fair to say that the tax provisions are designed to reduce the government's exposure to abandonment costs. However, they do have the effect of postponing the state's share of the disposal costs, and the sharing rule provides the government with incentives to internalise disposal costs. Still, the particular disposal cases reveal more of environmental concern than cost conscience on part of the government, reflecting the priorities of the political parties. It is too soon to judge on these issues, though, since some large disposal candidates have been postponed.

Another important objective of tax treatment of disposal costs is to avoid distortions in the companies' decisions, in particular distortions that reduce the recovery rate. Traditional tax treatment of removal costs might tempt the firms to close down production early, while they have sufficient revenue, and refrain from building out adjacent reservoirs (satellite fields).

A reason why the oil companies were not allowed appropriations in the tax accounts for future removal costs, (a), was perhaps the fact that this approach might imply large tax advantages for the oil companies: because neither the timing nor the extent or costs of future removal could be established with a reasonable degree of certainty at the time of appropriations, these would be arbitrary. Implicit in this argument is the belief that the companies would have an incentive to exaggerate future removal costs, e.g., by underestimating the expected cost reductions due to advances in technology, and thereby obtain undue tax credits.

In addition to refunding parts of the companies' share of the removal costs, the Norwegian state would also have to carry the costs that accrue to the state equity share in the various licences. Assuming that the private oil companies in a given licence have been in a tax paying position for the entire period of operation, and that the SDFI holds 30 per cent of the licence, Statoil 20 per cent, and Norsk Hydro 15 per cent, the Norwegian state is to pay 90 per cent of the removal costs.[20] If Statoil and SDFI together held 80 per cent of the equity (which is the case for some licences), the state would be accountable for 97 per cent of the removal costs.[21]

4. Externalities to fisheries from oil installations

In several areas around the globe, such as off the Norwegian coast, the most important externalities from offshore petroleum installations are to the fishing industry. Offshore oil activities have made considerable fishing areas inaccessible for fishing vessels. Hence, the disposal choice for obsolete installations may have significant economic consequences to fisheries. This section analyses the nature of externalities to fisheries, and provides estimates from a case study of the Ekofisk field on the Norwegian continental shelf.

Offshore petroleum installations and pipelines occupy considerable areas in the Norwegian sector that were previously used as fishing grounds or represent potential fishing grounds. Most oil installations have a safety zone that is closed to fishing vessels. Pipelines on the seabed have a reputation for damaging demersal trawl gear (Soldal, 1997). In addition, a large number of objects have been dumped on the seabed in conjunction with oil activities, leading to damage or loss of fishing gear.

[20] Note that if the companies have partly been out of a tax paying position, e.g., with an average tax rate of 30 per cent, the state's share would be considerably lower.

[21] The state's equity share, however, has been reduced in recent licensing rounds.

For both the fisheries and petroleum sector most of the production is exported. In 2000, exports of products from the seafood sector totalled US$ 3.4 billion. This is much less than the export revenues of US$ 28.8 billion from the petroleum sector. But unlike the latter sector, fisheries should be able to maintain income streams around the current levels into an indefinite future. The Norwegian fishing industry employed 22,900 fishermen in 1997, while 16,000 were employed offshore and onshore in petroleum extraction. However, the greater short-term magnitude of petroleum revenues may have lead to a favourable treatment of the petroleum sector in areas where the two sectors have had conflicting economic interests.

There exist no estimates of the total costs to fisheries due to loss of access, damages to equipment and pollution in the Norwegian sector. The estimated losses in estimated individual sectors are of minor significance, both in absolute terms or when compared to total revenues from the Norwegian fishing sector. However, with a gradual shift in petroleum activities from the southern waters of the Norwegian sector to the northern waters, where fish resources are much larger, the trend is that new petroleum installations are located closer to the more important fisheries.

Until recently, the focus has been on the effects of new production facilities on fish stocks and fisheries. However, as some oil fields now approach their terminal phase, the focus is shifting towards disposal options for installations. An important topic is the potential externalities associated with different disposal options. Although petroleum activities are generally being regarded as a source of negative externalities to the fisheries sector, it is recognised by some that there may be benefits from installations that have reached their cold phase. There are several issues that need to be considered in an analysis of externalities to fisheries from abandoned installations.

- *Stock pollution*: Are there any toxic emissions from abandoned installations that can lead to increased mortality and/or reduction in the market value of the fish?
- *Stock enhancement effect*: Does the physical presence of oil installations increase the reproductive ability of fish stocks (fishing reefs), thus leading to an increase in fish biomass and harvesting potential?
- *Stock oncentration effect*: Will the fish stocks gravitate towards the feedstock that tends to gather around offshore installations?
- *Fishing access*: To what extent does the physical presence of obsolete installations and pipelines limit the accessibility of different types of fishing vessels and different gear types?

There is no general answer to the question whether abandoned oil installations will pollute the surrounding fish population. However, it is anticipated that for the installations in the Norwegian sector the costs associated with cleaning up after termination of production should be relatively small. The most visible pollution is usually pile cuttings on the seabed (Anon., 1999). The environmental impact has not been such that it has affected the prices of fish caught in the area.

The above biological and technological factors together determine which disposal option is most beneficial to fisheries. In the following, we discuss these factors in more detail, partly with reference to studies of the Ekofisk field on which we shall focus in the subsequent case study.

It is a conventional wisdom among fishermen that the areas around ship wrecks are often good fishing grounds (Valdemarsen, 1978). Several studies also suggest that offshore platforms may have beneficial effects for fisheries, because they serve as artificial reefs that attract fish and also enhance the stock by allowing for an increased recruitment of juveniles to catchable size. The behaviour of fishing vessels in the North Sea also provides strong indications of the potential economic value of having oil installations as artificial reefs. Trawlers tend to fish in a circle as close to the safety zone of the platforms as possible. For instance, around the Ekofisk field Scottish purse seiners are involved in an intensive haddock fishery in periods (Soldal et al., 1999, p. 25). In the Gulf of Mexico there is competition between commercial and leisure fisheries for the fishing grounds around abandoned platforms (Reggio, 1987; Gurney, 1992). Despite a large research effort in several countries, however, there is no international consensus on whether artificial reefs have a significant stock *enhancement* effect or only positive stock *concentration* effects (Soldal et al., 1999, p. 80). There is probably no general answer, since reef effects depend on the characteristics of the marine environment in the particular area, such as fish species composition, nutrient conditions and topographical conditions.

The introduction of a reef gives three possible scenarios for the total fish biomass and its distribution at a fishing ground: (1) introduction of reefs leads only to a stock concentration around the reefs, (2) reefs cause both stock enhancement and stock concentration, and (3) the reef causes only a stock enhancement effect, because the increased stock of fish migrates from the reefs to the surrounding areas, leading to a fairly even distribution of the biomass in a larger area. Hence, the question is not only what effects artificial reefs have on the *total biomass*, but also what effects they have on the *spatial distribution* of the biomass in the areas around the reef.[22]

Reefs can increase the economic rent through an increase in sustainable harvest or a reduction in cost per unit of harvest. The economic rent of the fishery can increase even if the petroleum installations only have a stock concentration effect. This is because an increased concentration of the biomass around a reef can lead to an increase in the harvest rate per unit of time, since the time needed to search and fish is reduced. A necessary condition for an increase in the economic rent is that the fishing industry does not have to introduce fishing technologies that are more costly per unit of harvest.

If artificial reefs have a stock enhancing effect, and the fish migrates from the reef to surrounding areas, then some very interesting possibilities may open up for the regulation of the fishery. By creating a marine reserve around the reef to protect the reproduction of the fish stock, the regulator can secure a steady supply of biomass for harvesting in the adjacent areas.[23] There will be a net benefit from creating a reserve, if the migration from the reserve area around the reef is sufficient to provide for an increase in the sustainable harvest that is larger than the foregone harvest in the marine reserve. Some fishing technologies may be physically prevented from operating in the vicinity of oil installations. Evidence from other countries suggests that efficient exploitation close to reefs requires specialised reef fisheries utilising a suitable gear.

Tveterås and Osmundsen (1999) provide estimates of the externalities to the fishing industry from obsolete Ekofisk installations. The estimates are derived under different fish population dynamics scenarios, using available fish stock data in the area. Sensitivity analyses were undertaken to provide estimates of the economic significance of oil installations as artificial reefs. Five scenarios were considered. In the first scenario the substructures of the platforms are removed and the only beneficial effect is the opening of the area to fisheries. The other four scenarios assume that the substructures are kept in place. In the second and third scenarios fishing vessels are allowed to fish freely close to the abandoned installations. However, in scenario two 10 per cent of the biomass can be harvested by demersal trawlers due to fish migration to surrounding areas, while in scenario three the fish stock is only available to vessels with reef fishing technologies. In scenarios four and five, a marine reserve is created around the abandoned installations, i.e., reef fishing vessels are excluded from the area. In the fourth scenario the fish migrates to the surrounding open areas, thus making all of the sustainable harvest available to demersal trawlers. The mobility of the fish is assumed to be smaller in the fifth scenario, thus leaving only 20 per cent of the biomass to be harvested by demersal trawlers, while the remaining 10 per cent of the sustainable catch is lost due to mortality within the marine reserves. The marine reserve scenario four provides the highest rent. However, the estimated rent is small, only 3.9 million USD in net present value terms, less than 1 per cent of the estimated removal costs.

5. Summary and conclusions

This paper has examined major policy issues associated with decommissioning of petroleum installations, using the Norwegian continental shelf as a case study. Decommissioning is becoming an increasingly important issue, as many offshore petroleum fields around the world are approaching the time when their reservoirs are exhausted. The Brent Spar incident suggests that this is also a politically potent issue extending across national boundaries. International conventions, most notably the OSPAR agreement, still allow for a large degree of discretion on the part of national governments in the case of pipelines and large installations.

By signing international agreements such as the OSPAR, governments have constrained themselves to choosing decommissioning options with limited adverse environmental effects.

[22] There are two biological studies of the potential reef effects of the Ekofisk field installations. According to Cripps and Aabel (1998) the existing working platforms in the Ekofisk area "are having a small, beneficial effect on local fish populations" (p. 15).

[23] One advantage of such a marine reserve is that it should be possible to monitor the movement of vessels around the reef(s) at relatively low costs, by installing a radar on one of the installations.

The costs of decommissioning programs depend on the choice of strategy. However, the decommissioning strategy not only influences costs, but also which parties are going to carry the costs. Potential winners and losers are oil companies, tax-payers, and different groups of fishing vessels. Hence, decommissioning is a cost–benefit problem involving important distributional considerations, with binding political constraints represented by the national and international environmental opinion, as well as tax-payers' willingness to pay for a clean seabed.

Disposal of petroleum installations raises a number of interesting questions. Examples are timing issues, tax treatment, and liability for installations that are permanently left at the seabed. New technology and discovery of new reserves in adjacent areas may make it optimal once again to use the facilities for extraction purposes. Thus, it may be optimal to postpone the disposal of platforms.

In a case study of the Norwegian continental shelf we saw that removal costs are of a very different order of magnitude for the Odin field and the Ekofisk field. The experience from the Ekofisk field suggests that, when removal costs are large, both government and oil companies prefer to defer. Since there are other fields with removal costs of a similar magnitude, one may see an accumulation of non-producing petroleum installations over time for which removal is deferred, until one reaches a point when the total accrued removal costs are too large to be carried by the society, with the effect that large parts of the installations are left standing at the abandoned fields indefinitely.

Petroleum installations may function as artificial reefs that may provide positive fish stock concentration and enhancement effects, generating possible gains to specialized artificial reef fisheries but losses to demersal trawlers that will not be able to access the area. Calculations from the Ekofisk field at the Norwegian continental shelf show that leaving the installations as artificial reefs and establishing a marine reserve around the abandoned installation, is the option that generates the highest net present value to the fisheries. However, the future discounted net revenues for fisheries are small, less than 1 per cent of the disposal costs.

The most influential Norwegian fisheries organisation opposes artificial reefs. Adding the fact that environmental organisations strongly oppose reef programs, as well as the fact that the Norwegian government previously has not approved such applications, it is perhaps not surprising that the Ekofisk field operator, Phillips Petroleum, proposes to take the steel substructures on the Ekofisk field ashore. This disposal solution is estimated to cost 460 million USD, compared to 100 million USD for artificial reefs. For this decommissioning decision to be in correspondence with society's cost–benefit calculations, the population's willingness to pay for a clean seabed in this particular area must exceed the net loss to fisheries of removing the installations and the cost difference of removing installations, e.g., it must exceed 363.9 million USD in the case of Ekofisk. It is worth noting that Norway has a small population (5 million) and a large number of offshore platforms. In the area surrounding the Ekofisk field, there is a low fish density and a small share of the fish biomass is high value species. Thus, other areas on the Norwegian shelf have a considerably larger potential for increase in fish biomass and economic rent through an artificial reef program.

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