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DISPOSAL 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 and disposal policy. Optimal disposal policy can be analysed by cost-benefit analyses with distributional effects, subject to environmental and goodwill constraints.

Keywords: Petroleum installations, decommissioning, disposal, externalities

JEL Classification: D62, G18, H32, L51, L72, Q48

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1. Introduction

Disposal of obsolete offshore petroleum installations is a relatively new issue involving billions of dollars globally.[1] Powerful players – multinational oil companies, environmental organizations and governments – all have high stakes here. A major point of dispute is the magnitude of social costs in terms of externalities to other users of the marine environment.

In Europe the public became aware of the platform decommissioning issue after the debate over the disposal of Brent Spar. The Brent Spar was taken out of operation in 1991 after some 15 years' service in the Shell / Esso 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 Best Practicable Environmental Option (BPEO). It was concluded that deepwater disposal would have had negligible impact on the marine environment and this was confirmed by independent scientists. The UK Government approved this original plan in February 1995, and also informed the European Union and the twelve countries in continental Europe which have signed the Oslo Convention for the protection of the marine environment.

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.[2] The new decision was approved by the UK government. This disposal solution has been costly to Shell, disposal costs increased from an estimated 38.5 million USD for a deepwater disposal to final total of 71.4 million for the onshore dismantling, according to Shell (Lode, 1999).

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[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] The installation was towed to Erfjord in Norway, pending the decision on disposal. It was decided that Wood-GMC should partition the buoy and use it as a fundament for a Norwegian Ro/Ro ferry quay.

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.[3] In spite of the interesting policy issues and the large sums involved, decommissioning and disposal of petroleum installations seems to have been given scant attention by researchers of economics.

There are more than 6500 offshore installations world-wide, with an estimated overall removal cost of 20 billion USD. There are a great variety of installations, each designed for a particular set of conditions; ranging from fixed shallow-water structures in 30 metres of water to tension leg platforms in 900 metres 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 metres 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.

2. International Decommissioning Issues

A typical platform consists of the *topsides*, which contains the drilling, processing, utilities and accommodation facilities, and the supporting *substructure* or *jacket*. Steel jackets can 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 sit 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

[3] Shell UK Exploration & Production requested Det Norske Veritas (DNV), the international certification, classification and advisory body, 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.

the platform are in contact with hydrocarbons and may contain potentially hazardous substances, whereas the substructure or jacket is generally clean steel or concrete.

An important topic in the public discussion over various disposal options, is the external effects on fisheries from petroleum installations. These effects have been part of the qualitative discussions, but efforts have not been made to estimate the size of the externalities. Estimates for external effects on fisheries are 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 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) Total or partial removal

- Emplacement / toppling on site
- To shore for recycling or disposal as waste
- Deep water disposal
- Artificial reefs
- Re-use / other uses

Artificial reefs means 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. 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 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 metres of water and weighing less than 4,000 tonnes in air, excluding the topsides, must be entirely removed.[4] Platforms exceeding those limits need to be cut off to allow 55 metres of clearance between their highest point and the surface. The water depth limit will increase to 100 metres 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, which were into one convention (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] 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, see Amundsen (1997). In determining optimal removal date, the oil companies would 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 in addition 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 (this is a new industry that is at the very start of its learning curve), (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 seem to have influence both on international legislation and on actual disposal decisions, are the *existence value of environmental goods or 'bads"* and *reputation effects.* Although few individuals may physically experience obsolete offshore oil installations, one should

[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 metres, only these two countries 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.

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 may have a desire to keep the oceans close to their "natural" state. For example, many individuals do not like the thought of oceans devoid of blue whales, although they will never be able to see these animals first-hand. Analogously, individuals may not like the idea of using the ocean 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 has a positive willingness-to-pay for the non-existence 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, and a positive reputation may provide the holder with goodwill capital. If a country's (or company's) decommissioning policies leads 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 were willing to incur extra costs to have these reduced (SNF, 1998, chapter 4).

3. Norwegian Decommissioning Policies

The Norwegian Parliament sanctioned the OSPAR Convention. However, there is a number of large installations on the Norwegian continental shelf for which disposal is not regulated directly by the Convention. Concrete installations and steel jackets with weight higher than 10.000 tonnes are excepted from the OSPAR ban on sea disposal. For concrete installations, the Norwegian government has full discretion, i.e., they may be fully of 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], i.e., the jacket may be left on the seabed but not dumped elsewhere. [8]

[6] See proposition from the Norwegian government, St. prp nr 8, 1998-99.

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

After February 9, 1999, however, all new steel installations must be designed so that total removal is feasible.

Characteristic features of the Norwegian continental shelf are high deeps and large reservoirs, developed by large installations. Thus, the cost of decommissioning in the Norwegian sector is on average considerably greater than in the rest of the world. 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 in 1994. New technology and the development of a decommissioning industry is 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 accumulated investments on the Norwegian Continental Shelf at that time, in comparison, were 100 billion. Nevertheless, adding the fact that the Norwegian government will carry most of the costs, and that the major part of these costs will come in a period when petroleum revenues are declining and the number of retirees is increasing, decommissioning will be a considerable fiscal burden for Norway. By establishing a considerable petroleum wealth fund (approaching 30 billion USD), however, the Norwegian authorities should have means for smoothening out this effect.

The procedure for decommissioning decisions are as follows. The license owners, represented by the operator, develop detailed decommissioning and disposal plans, examining and evaluating different decommissioning and disposal options. The conclusions of these plans, reflecting the licensees' preferred option, are thereafter handed over to the government (together with the documentation) and at the same time circulated to a number of environmental and fisheries organisations, that are given the opportunity to give their comments. The plan is thereafter reviewed by the Ministry of Petroleum and Energy. The ministry considers environmental, technical, economic and resource aspects. Furthermore, it takes into account international obligations, the consequences for fisheries and shipping, and the comments of environmental and fisheries organisations. Typically, the recommendation from the Ministry to Parliament (Stortinget), is somewhere between the recommendations given by the licensees and those of the environmental and fisheries organisations.

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[8] Provided 55 metres of clear water is present over the remains to ensure safety of navigation.

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

The latter typically advocate a complete removal of all installations, whereas the former often would like some of the facilities to remain on the field or to be dumped. The Ministry has recommended only special facilities, like pipelines, to remain ashore. In the recommendations to Stortinget it has been emphasised that each field is unique and that the recommendations are not intended to form precedent. Existing Norwegian offshore petroleum installations are very heterogeneous with respect to decommissioning aspects such as external effects and removal costs, calling for a separate cost-benefit evaluation of each case.

3.1. Two Decommissioning Cases: The Odin Field and the Ekofisk Field

A major part of offshore installation disposal costs are mobilising and demobilising costs for specialised vessels used for emoval. 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.

For Norwegian installations 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 has never been viewed as politically acceptable, and has never been considered an option.

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 taking the installation on shore, and it 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 disposal study headed by Exxon evaluated three different disposal options for the topside and the modules[12]:

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[10] See proposition from the Norwegian government, St prp nr 36, 1994-95.

[11] See proposition from the Norwegian government, St prp nr 8, 1998-99.

Table 1. Disposal Options for Topside and Modules

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

The licensees recommended alternative (a). This was supported by the Ministry, being the best solution in both economic and environmental terms. Analogous calculations were made for the substructure:

Table 2. Disposal Options for Substructure

Alternative	Estimated cost (Mill USD)
(a) Remove and take ashore for recycling	12.9
(b) Remove and dispose on deep water	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 on the Norwegian Continental shelf. A condition from the oil companies for choosing this solution was that the ownership and the liability of the remaining installation was transferred to the Norwegian state, without the licencees paying any compensation to the state. As for environmental impact, recycling of steel would (compared to new production) reduce omissions of CO2 equivalents and NO2 with 21,000 and 35 tonnes, respectively. The Ministry recommended alternative (a); the savings of 4.5 million USD was 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.

[12] See proposition from the Norwegian government, St. prp. nr. 50, 1995-96.

The costs of removing and recycling the pipelines on the Odin field was estimated to 8.7 billion USD. The licencees recommended the pipelines to remain on the seabed, after being properly cleaned. Being used to transport gas, the pipelines would be free of heavy petroleum remainings. The Ministry postponed the decommissioning decision of the pipelines, pending environmental evaluations and discussions of whom is to be liable for installations that are left permanently on the seabed, and the size of compensation if liability is transferred.

The Ministry's disposal recommendations for the Odin field was similar to those of 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; possible environmental effects could not justify the considerable removal costs (11 million USD).

Phillips Petroleum, the operator of the Ekofisk field on the Norwegian continental shelf, has recently presented a two-stage decommission and disposal 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 are a total of 34 installations, including flare stacks, at the Ekofisk and associated fields. Of these, 25 are main structures, amounting to 3.5 mill 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 meters.

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[13] See proposition from the Norwegian government, St prp nr 36, 1994-95.

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

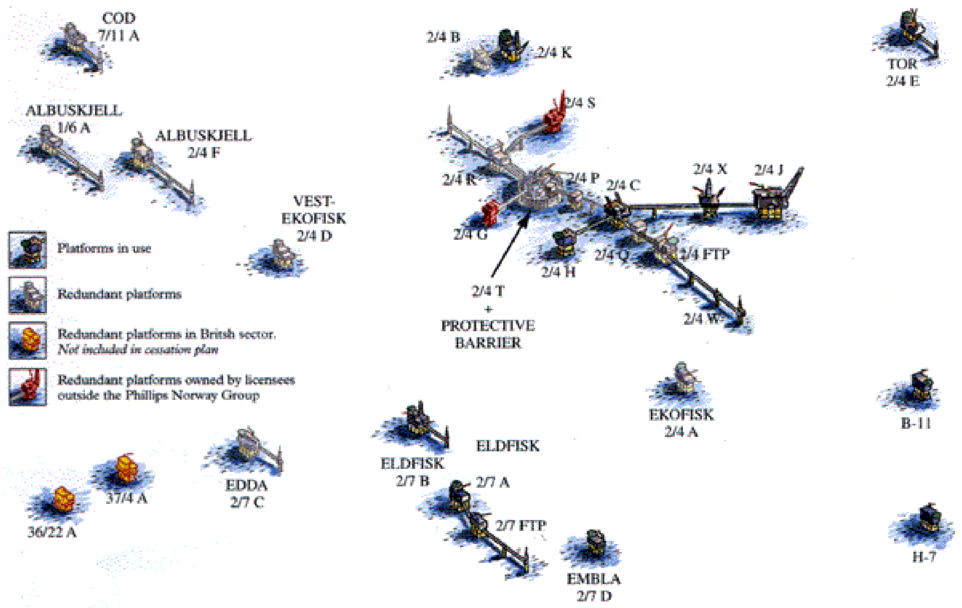

Figure 1. The Installations of The Ekofisk and Associated Fields (Source: http://www.phillips66.no)

In 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 reuse. This operation will begin in 2003, with estimated costs of 0.7 billion. In 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. Phillips expects that new removal technologies will be introduced before 2015, thereby reducing the removal costs for the substructures. Some of these substructures have to be removed under the OSPAR convention, while an exception is made for a concrete substructure weighing 1,2 mill. tonnes which may be left ashore.

3.2. Tax Treatment of Decommissioning and Disposal

Decommissioning and disposal raise some interesting tax questions. As a background for this discussion we first present the general features of the Norwegian petroleum taxes. The Norwegian petroleum tax system is based on the Norwegian rules for ordinary corporate tax, charged at 28 per cent. Owing to petroleum 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 silent 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. Recently, there has been political discussions about a partial privatisation of Statoil, and about possible changes in the ownership of the SDFI.

As for tax treatment of disposal 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. The cost sharing rule is thus 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 decommisioning of 15 platforms at the Ekofisk field, starting in 2003, the state is to pay about two thirds of the removal costs according to a recent press release from Phillips Petroleum.[17] There is, however, exceptions to this main 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, 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] In calculating the revised cost share, the government has taken into account the company's *future* tax position in Norway [19] (since there is no ring fence in the Norwegian petroleum tax code, the company is the relevant tax subject), i.e., scheme (b) is applied. Thus, while the main rule is (a), rule (b) may be

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[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 CO2-tax is likely to be reduced.

[16] For more details on the Norwegian petroleum tax system, see Fact Sheet 1998.

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

[18] See proposition from the Norwegian government, St. prp. nr. 50, 1995-96.

[19] See St. prp. Nr. 36, 1994-95

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. nr. 33, 1985-86), the reason why the oil companies was not allowed appropriations in the tax accounts for future removal costs, was that this approach might imply large tax advantages for the oil companies: because neither the timing nor the extent of 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, by a careful auditing practice or by strategic reporting would have an incentive to overstate future removal costs (e.g., by underestimating the expected cost reductions due to advances in technology), thereby obtaining undue tax credits. We might add the political argument that the incumbent government might prefer the drop in state revenue be borne by future governments.

In addition, the Norwegian state has 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. These are extreme cases, though. Often the companies have only been in a tax paying position for parts of the period of extraction. Also, the state's equity share has been reduced in recent licensing rounds.

4. Externalities to Fisheries from Oil Installations

In several areas around the globe, for example, 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.

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

For both the fisheries and the petroleum sector most of the production is exported. In 1997 exports of products from traditional fisheries were 2.3 billion USD. This is much less than the export revenues of 21.9 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 two sectors are more comparable with respect to employment, with fisheries being the largest in terms of direct employment. The Norwegian fishing industry employed 22,900 fishermen in 1997, while 16,000 were employed offshore and onshore in petroleum extraction.

There exist no estimates of the total costs to fisheries due to loss of access, damages to equipment and pollution in the Norwegian sector. A government report from 1986 analyses losses to fisheries for some selected areas with petroleum extraction (NOU, 1986:6). It estimates the reduction in annual catch revenues due to petroleum activities to represent 23 % of the catch potential *in these areas*, or nominal 1986 3.3 million USD. The estimated losses are of minor significance 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, focus has been on the effects on fish stocks and fisheries of installing new installations However, as some oil fields now approach their terminal phase the focus is shifting towards disposal options for installations which have ceased producing. 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 recognized that there may also be benefits from installations which have reached their cold phase.

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[20] 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 42 per cent.

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 value of the fish?
- *Stock enhancement effect*: does the physical presence of oil installations increase the reproductive ability of fish stocks, thus leading to an increase in fish biomass and harvesting potential?
- *Stock concentration 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?

4.1. Stock Pollution

There is no general answer to the question whether abandoned oil installations will pollute the surrounding fish population. However, it can be expected 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). Studies of the fauna in the Ekofisk area show that the faunal diversity increases with increasing distance from the fields. The benthos has been disturbed by the oil related activity, but the environmental impacts of the Ekofisk center field appears to have decreased from 1990 to 1996. None of the sites at the Ekofisk Center, which is the most affected area, were highly disturbed in 1996 (Cripps *et al*., 1998, sect. 1.6). Furthermore, the environmental impact has not been such that it has affected the prices of fish caught in the area.

4.2. Stock Concentration and Stock Enhancement Effects

The combined effect biological and technological factors 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.

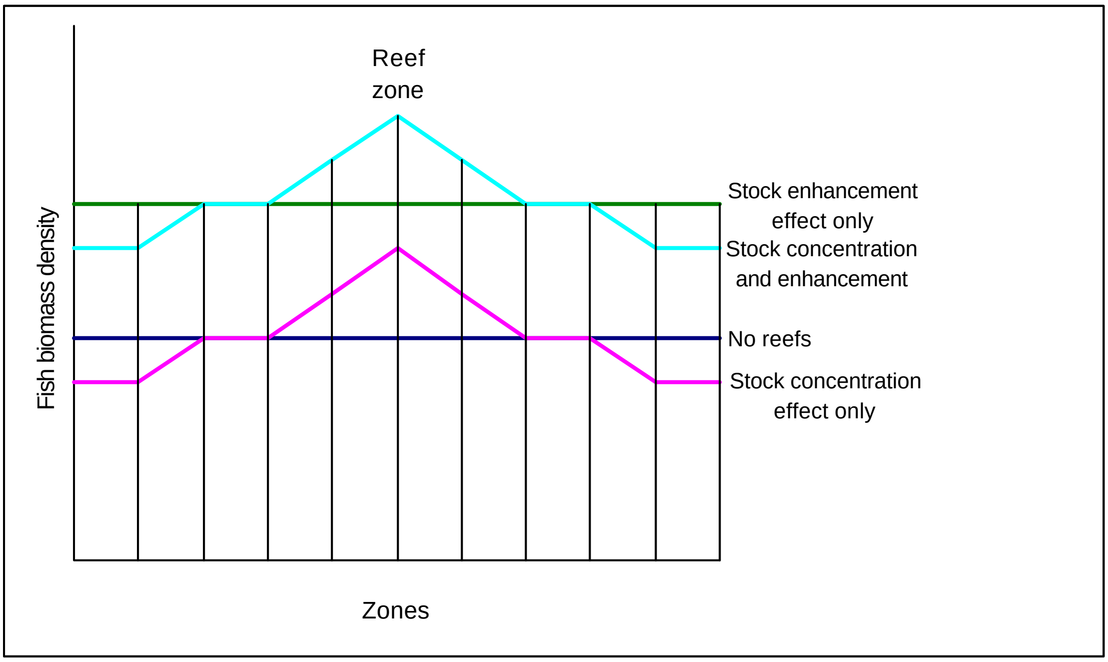

Figure 2. Fish Biomass Distribution under Three Different Reef Effect Scenarios

It is 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 to 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 (Ditton and Falk, 1981; Driessen, 1985; Aabel *et al*., 1997). The behavior of fishing vessels in the North Sea also provides strong indications of the potential economic value of oil installations as artificial reefs. Trawlers tend to fish in a circle as close to the safety zone of the platforms as possible. Around the Ekofisk field Scottish purse seiners are involved in a intensive seasonal haddock fishery (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 has a significant stock *enhancement* effect or only has a 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 and topographical conditions.

Figure 2 depicts three different scenarios for the total fish biomass and its distribution at a fishing ground when a reef is introduced. One scenario is that introduction of reefs only leads to a stock concentration around the reefs. Another alternative is that reefs cause both stock enhancement and stock concentration. A third scenario is that reefs lead to an increase in total biomass, but that the fish migrates from the reefs to the surrounding areas, leading to a fairly even distribution of the biomass in a larger area (i.e. only a stock enhancement effect). As figure 2 suggests, 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.

There are two studies of the potential reef effects of the Ekofisk field installations. According to Cripps, Forsberg and Aabel (1998) the existing working platforms in the Ekofisk area "are having a small, beneficial effect on local fish populations" (p. 15). They point out, however, that there is much uncertainty regarding the degree to which installations will concentrate fish, and what the effect will be on total fish stocks in the larger region. The fish stock found around individual operating North Sea platforms is small in relation to the overall stocks of fish in the North Sea.

Soldal *et al*. (1999) found increased fish densities compared to the surrounding sea area around the Ekofisk installation, Albuskjell Fox (2/4F), and an installation located at a different oil field, the Gullfaks C. They estimate the biomass of cod and saithe around Albuskjell Fox in the range of 10 to 100 tonnes, but stress that this estimate is very uncertain (p. 82). However, Soldal *et al*. (1999) found mostly cod larger than 50 cm and little juvenile fish close to the Albuskjell Fox installation. Based on this finding Soldal *et al*. argue that the Ekofisk installations probably may not function as protection zones for juvenile fish, implying that the stock enhancement effect may be limited. However, they stress the uncertainties surrounding their findings on fish population dynamics at the Ekofisk field, and conclude that more research is needed.

4.3. The Economics of Artificial Reef Fisheries

Artificial reefs may have significant effects on the economics of fisheries, at least on a local scale. They can influence the total economic rent, the spatial distribution of fishing effort, and the distribution of income between different fishing vessel groups.[21]

[21] The bioeconomic analyses of Sanchirico & Wilen (1998, 1999) do not focus explicitly on artificial reefs, but their model framework could be utilized in analyses of reef effects.

Reefs can increase the economic rent through an increase in sustainable harvest or a reduction in cost per unit of harvest. Figure 2 suggested that there are several scenarios which should be considered. 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 fishing time. 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.

If artificial reefs has 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 (where fishing is not permitted) to protect the reproduction of the fish stock, the regulator can secure a steady supply of biomass for harvesting in the adjacent areas.[22] If the migration from the reserve area around the reef is sufficient to provide for an increase in the sustainable harvest outside the reserve that is larger than the foregone harvest in the marine reserve, then there will be a net benefit from creating a reserve.

Some fishing technologies may be physically prevented from operating in the vicinity of oil installations. Evidence from other countries suggest that efficient exploitation close to reefs requires specialized reef fisheries utilizing suitable gear. Seine or trawl may be unsuitable for use close to the platforms, whereas long-lines may be used. Use of stationary nets (e.g. gill nets) by experienced fishermen is another possible alternative for close-reef fisheries. Since the efficiency of different fishing technologies varies close to reefs, the fish population dynamics generated by the reefs should have a significant effect on the distribution of income between different technologies. The creation of marine reserves around installations may also have redistribution effects if some fishing technologies that could otherwise exploit the artificial reefs are closed out, and the fish is instead harvested by demersal trawlers in the surrounding open areas.

4.4. Estimates of Reef Effects at the Ekofisk Field

In this section we provide some tentative estimates of the externalities of obsolete Ekofisk installations to the fishing industry under different fish population dynamics scenarios. Since substructures are not to be removed until year 2015 it would be useful to obtain more knowledge on the nature and size of externalities before irreversible removal decisions are made.[23]

The sea areas surrounding Ekofisk have a relatively small economic importance for the Norwegian fishing industry, representing only around 6% of the total volume and 2% of the total first hand value of Norwegian fisheries. Low value sandeel fisheries is dominating in the areas surrounding Ekofisk (SNF, 1998, pp. 12-13).

By using information on vessels from the Directorate of Fisheries, and data on fish stocks around oil installations recently collected by the Institute of Marine Research and others[24], it is possible to set reasonable value ranges for the parameters. Sensitivity analysis can then be undertaken to provide estimates of the economic significance of oil installations as artificial reefs for the fishing industry. Table 3 provides some rough estimates of net benefits to fisheries under different scenarios for platform disposal, fish stock migration and regulation. This analysis is by no means exhaustive, but provide some indications on the absolute magnitude of externalities and the relative outcomes in the different scenarios.

Costs may vary considerably between vessel groups. Fishing costs per kilo of harvest may be as high as 0.7 USD for certain vessel types that are suited for reef fisheries, and as low as 0.10 USD for demersal trawlers which are prevented from operating in the vicinity of oil installations.[25] Here, we assume 0.4 USD and 0.15 USD for reef fishing vessels and demersal trawlers, respectively.

The biomass is assumed to consist mainly of the high-value species cod, haddock and saithe, which have been observed in large numbers around the Ekofisk platforms.[26] Based on Serchuk *et al*. (1996), we assume that 30 % of the biomass can be harvested each year. Our average price estimate is based on 1997 ex vessel prices from the central North Sea (area 41) reported by the Directorate of Fisheries.

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[22] An additional 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.

[23] A more extensive and formal discussion of the fish population dynamics and economics of reef fisheries is provided in Tveterås & Osmundsen (1999).

[24] Budsjettnemnda, 1997; Cripps, Forsberg & Aabel, 1998; Fiskeridirektoratet, 1997; Soldal *et al*., 1999.

[25] Budsjettnemnda, 1997; Fiskeridirektoratet, 1997.

[26] Cripps, Forsberg & Aabel, 1998; Soldal *et al*., 1999.

In scenario I 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. Here it is assumed that each platform holds a biomass of 60 tonnes. If platforms are removed the sustainable biomass is reduced to 10 tonnes. Hence, the stock enhancement effect is assumed to be equal to 50 tonnes per platform. In scenario II and III, fishing vessels are allowed to fish close to the abandoned installations. However, in scenario II, 10% of the biomass can be harvested by demersal trawlers due to fish migration to surrounding areas, while in scenario III the fish stock is only available to vessels with reef fishing technologies. In scenarios IV and V a marine reserve is created around the abandoned installations, which means that reef fishing vessels are excluded from the area. In scenario IV 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 scenario V, thus leaving only 20% of the biomass to be harvested by demersal trawlers, while the remaining 10 % of the sustainable catch is lost due to mortality within the marine reserve.

Table 3. Estimates of Net Benefits to the Fishing Industry under Alternative Scenarios

Scenario	I. Platform Removal	II. Reef Fisheries 1	III. Reef fisheries 2	IV. Marine Reserve 1	V. Marine Reserve 2
Sustainable biomass	10	60	60	60	60
Sustainable catch	0.3	0.3	0.3	0.3	0.3
% harvested by reef vessels	0	0.2	0.3	0	0
% harvested by demersal trawlers	0.3	0.1	0	0.3	0.2
Average price/kilo (USD)	1.14	1.14	1.14	1.14	1.14
Cost reef vessels/kilo (USD)	0.43	0.43	0.43	0.43	0.43
Cost demersal trawlers/kilo (USD)	0.14	0.14	0.14	0.14	0.14
Total net revenues, reef vessels	0	120,000	180,000	0	0
Total net revenues, demersal trawlers	42,000	84,000	0	252,000	168,000
Total annual net revenues (USD)	42,000	204,000	180,000	252,000	168,000
Net present value, total revenues*	642,000	3,118,000	2,751,000	3,852,000	2,658,000

* Discount rate 7 %.

Under these assumptions, we see from table 3 that the marine reserve scenario IV provides the highest rent. However, the rent is in approximately the same order of magnitude in all the scenarios in which platforms are kept in place, suggesting that the ranking is sensitive to changes in underlying assumptions. The platform removal scenario provides a significantly smaller rent than the other scenarios, a result that holds under reasonable changes in parameter values.

It is evident from table three that disposal decisions, fish migration patterns and regulatory regimes not only influences the total economic rent from the fisheries, but also the distribution of rent between different fishing technologies. In all of the scenarios, though, the net benefits to the fisheries are negligible compared to disposal costs.

5. Summary and Conclusions

This paper has examined major policy issues associated with decommissioning of petroleum installations, with case material from the Norwegian continental shelf. Decommissioning is becoming an increasingly important issue, as many offshore petroleum fields around the world are approaching the date when their reservoirs are exhausted. The Brent Spar incident suggests that this also a politically potent issue extending across national boundaries. International conventions, most notably the OSPAR agreement, still allow for a considerable degree of discretion on the part of national governments in the case of pipelines and large installations. For a considerable proportion of the Norwegian installations that will become obsolete during the next years, disposal options can be decided at the national level.

By signing international agreements such as the OSPAR, the Norwegian government and other governments have constrained themselves to choosing decommissioning options with limited adverse environmental effects. The costs of decommissioning and disposal programmes depend on the choice of strategy. In addition, the strategies chosen are likely to have significant distributional effects. 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 with respect to the national and international environmental opinion, and tax payers' willingness to pay.

Disposal of petroleum installations raises a number of interesting questions. Examples are timing issues, tax treatment, and liability for installations. New technology and discovery of new reserves may make it optimal once again to use the facilities for extraction purposes. Thus,it may be optimal to postpone the disposal of platforms. Difficulties of estimating the future removal costs, raises the question of possible undue tax credits by allowing the oil companies appropriations in the tax accounts. For those type of installations that may be left permanently on the seabed, e.g., pipelines, there are interesting questions about which party is to be liable for the installations.

Petroleum installations are artificial reefs that may provide positive stock concentration and enhancement effects. This may have significance for disposal decisions, since the OSPAR convention provides an exception from the requirement that the substructures of installations weighing less than 10,000 tonnes should be taken ashore if they can be used in a planned manner for other purposes (Anon, 1998; Soldal *et al.*, 1999, p. 26).

The leaving substructures ashore would give net economic losses for fishing technologies that cannot be used in the presence of platforms and pipelines (e.g. demersal trawl), and net economic gain for specialized artificial reef fisheries. It is shown that obsolete installations which are not removed can, due to stock enhancement and concentration effects, provide a net benefit to the Norwegian fishing industry if some vessels adapt to the requirements of reef fisheries.

As implied by the above discussion, disposal decisions may have income redistribution effects within the fishing industry. Different vessel groups in the fisheries sector have different economic interests with respect to decommisioning. Large vessels which use demersal trawls may benefit from complete removal of installations and pipelines, while vessels employing gear suited for reef fisheries will benefit if installations are left in place. However, if the fish population dynamics is such that a marine reserve around the installations should be created, then demersal trawlers may be the beneficiaries.

It is shown, however, that in the Ekofisk area, future discounted net revenues from fisheries (under different disposal options) are insignificant compared to removal costs. The disposal option with the highest net present value only comprises 0.35 per cent of the disposal costs. Moreover, the most influential fisheries organisation, Southern Norway Trawler's Association, oppose artificial reefs. Adding the fact that environmental organisations strongly opposes reefs programmes, and the fact that the Norwegian government previously has not approved such applications, it is not surprising that 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. According to a company spokesman, one decisive factor in reaching the decision was that significant increases in fish biomass could not be established.[27] With the exception of long-line fishermen, all other related parties' statements indicated that they perceived artificial reefs as camouflaged dumping.

As for the precedent of this decision, however, it should still be noted that other petroleum fields have significantly higher density of fish and a higher fraction of high value species, thus having a potential for larger increases in fish biomass by a reef programme than is the case for the Ekofisk field.

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[27] *Stavanger Aftenblad*, 22 October, 1999,

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