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**Book**

# Is it necessary and feasible to estimate the asset value from oilfield level?

Statistisk sentralbyrå
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TALL SOM FORTELLER

NOTATER / DOCUMENTS

2024/8

In the series Documents, documentation, method descriptions, model descriptions and standards are published.



Published: 8 February 2024

ISBN 978-82-587-1909-7 (electronic)
ISSN 2535-7271 (electronic)

| Symbols in tables | Symbol |
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# Preface

This paper assesses the necessity and feasibility of estimating the asset value of petroleum resources on the Norwegian continental shelf from the oilfield level. It is the second outcome from an ongoing project ('Valuation of petroleum resources in Norway') at Statistics Norway, which is partly financed by Eurostat (Project number and acronym: 101122519, 2022-NO-SNA-UPDATE).

The authors want to thank Ståle Mæland, Håkon Frøysa Skullerud, Yun Walther-Zhang, Pål Sletten, Kristian Gimming, Steinar Todsen, and Trine Heill Braathu Randen for helpful discussions and comments. The paper also benefits from discussions by all participants in a seminar at Statistics Norway.

Statistisk sentralbyrå, 25.01.2024

Lasse Sandberg

# Abstract

This paper aims to assess the necessity and feasibility of applying the 'Bottom-up' approach at the oilfield level to estimate the asset value of petroleum resources on the Norwegian continental shelf by following the internationally recommended Net Present Value (NPV) method. The 'Bottom-up' approach estimates the resource rent and the asset value first from the oilfield level and then sums up the oilfields' results to arrive at an aggregate one. On the contrary, the 'Aggregate' approach considers the entire petroleum extraction industry as one production unit and calculates the resource rent and the asset value accordingly.

Assessment of necessity is implemented with a simple model, which demonstrates that under some simple and practical assumptions, the estimates by following the 'Aggregate' and the 'Bottom-up' approaches may coincide, implying that either of the two approaches can be equally applied in practice.

Assessment of feasibility is carried out by a thorough investigation on the availability of quality data at oilfield level. The conclusion is that data needed for applying the 'Bottom-up' approach that are in accordance with the National Accounts' concepts and of at least equivalent quality as those at the industry level are hard to be obtained, at least at present.

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# 1. Introduction

Due to very limited, if at all, information about market transactions in petroleum resources *in situ*, the asset value of petroleum resources is often estimated by following the Net Present Value (NPV) method, which measures the value of an asset as the sum of the discounted flow of future resource rents. The NPV method is recommended by the international statistical standards, such as the *System of Environmental-Economic Accounting 2012 – Central Framework* (hereafter SEEA-CF) (United Nations *et al*., 2014).

To estimate the asset value of petroleum resources on the Norwegian continental shelf by following the NPV method, there are in general two possible approaches, both relying on the availability of data needed. The first one is an 'Aggregate' approach which measures the total resource rents generated from the entire petroleum extraction industry covering the Norwegian continental shelf. The data inputs for this approach are mainly drawn from the Norwegian National Accounts (NNA).

The second one is a 'Bottom-up' approach which estimates the asset value of petroleum resources first from the disaggregated level, such as the oilfield level,[1] conditional on the availability of high-quality data at this level. Then by summing up the estimated oilfield results, the total asset value of petroleum resources on the Norwegian continental shelf can be obtained.

In Norway, measuring the asset value of petroleum resources on the Norwegian continental shelf as part of the national wealth has been carried out on several occasions (e.g., Brekke *et al*., 1989; Aslaksen *et al*., 1990; Lindholt, 2000; Greaker *et al*., 2005; Brunvoll, *et al*., 2012; Norwegian Ministry of Finance, 2012; Liu, 2016, 2023a) [2]. Not surprisingly, it is the 'Aggregate' approach that has been applied by these studies.

Recently, the 'Bottom-up' approach for measuring the asset value of mineral and energy resources is advocated, for example, by the OECD Task Force on the Implementation of the SEEA-CF (Pionnier and Yamaguchi, 2018), and by the Guidance Note prepared by UN Task Team working for updating the current *System of National Accounts 2008* (hereafter SNA) (Fixler, 2022). The main argument is that the heterogeneity of extraction costs across space has to be taken into consideration and the best way to do this is to work at the disaggregated level such as the establishment level.

The aim of this paper is to assess the necessity and feasibility of implementing the 'Bottom-up' approach for measuring the asset value of petroleum resources on the Norwegian continental shelf. In other words, the investigation will be undertaken as regards whether it is necessary and feasible to estimate the asset value of petroleum resources at the oilfield level on the Norwegian continental shelf.

The rest of the paper is structured as follows. Section 2 presents a simple theoretical model with the purpose to assessing the necessity. The stylized model demonstrates that the estimated results by following either the 'Bottom-up' approach or the 'Aggregate' approach may coincide under some simple and practical assumptions. In Section 3, the feasibility of implementing the 'Bottom-up' approach is explored, based on detailed investigations on the availability of high-quality data both consistent with the NNA concepts and needed for estimating the asset value of petroleum resources at the oilfield level. Section 4 concludes the paper with some remarks.

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[1] In this paper, an oilfield refers to a field producing not only raw oil but also the other types of petroleum products that have been found on the Norwegian continental shelf, such as natural gas, NGL, condensate, etc.
[2] For a brief overview on wealth accounting practices and its relationship with the work for natural resource accounting in Norway, see Liu (2013).

# 2. Assessment of necessity

In this section, an assessment will be made as regards whether it is necessary to apply the 'Bottom-up' approach. Certainly, there always exists some necessity, e.g., for making estimations by following both 'Aggregate' and 'Bottom-up' approaches, simply for comparison and cross-check purposes. But this is not our focus here, and the necessity assessment made in this paper aims primarily to gauge the potential differences between the two approaches, so that confidence may be enhanced, and uncertainty may be reduced, even if marginally, under the circumstance where only one approach can be implemented in practice. Such an assessment will be carried out by means of a simple theoretical model as presented in the following.

## 2.1. A simple model

Suppose there are *N* different oilfields operating and producing petroleum resource products on the continental shelf of a country in year *t*. Based on an information set that is formed at the beginning of year *t*, the following assumptions are made:

- For each oilfield *i* (*i* = *1*, *2*, ..., *N*), the expected remaining years for extraction of petroleum resources are $T_i$, with a constant annual production $x_i$ being projected for the future.
- Each oilfield *i* (*i* = *1*, *2*, ..., *N*) will face a basic price of its output of petroleum product as $p_i$, and the marginal cost per unit output of petroleum product as $c_i$.
- The resource rent is paid at the end of year *t* so that the resource rent generated in year *t* is discounted back to the beginning of year *t* by using a constant annual discount rate *r*.

Here it merits some discussions as regards the above assumptions. First, both the basic price $p_i$ and the marginal cost $c_i$, as well as the discount rate *r* can be formulated in either real or nominal terms. So long as all the corresponding nominal terms evolve in line with an expected general rate of inflation (such as the consumer price index (CPI)), there is no difference for calculating the resource rent and thus the asset value based on the NPV method. But what is important here is consistency, for example, it is not correct to combine nominal basic price and nominal marginal cost with a real discount rate and vice versa.

Second, the basic price $p_i$ and the marginal cost $c_i$ varies across oilfields that are indexed with *i* (*i* = *1*, *2*, ..., *N*), and thus the extraction costs' heterogeneity across the space at the oilfield level has been taken into account in the model setting.

Third, the assumption of constant basic price $p_i$ and marginal cost $c_i$ may not be far away from the reality, and they were used for theoretical modelling in order to rationalise empirical findings from industry practices (e.g., Cairns and Davis, 1998; Davis and Moore, 1998).

Fourth, the assumption of constant production $x_i$ may also make sense because according to the mining engineering literature, output at the mine or establishment level remains broadly constant due to constraints imposed by initial investments in fixed capital (e.g., Cairns, 2001).

Fifth, the end-of-year payment of resource rent is not an essential assumption in the modelling here, and the payment could be assumed to be made at the end of the year or at the middle of the year, but only with extra presentational complexity being involved (see e.g. Liu, 2023b).

All the assumptions made so far greatly simplifies the NPV computation. With this simple model setting being ready, the expected annual resource rent per unit of the petroleum products output in the future can be written as $(p_i - c_i)$, and the expected annual total resource rent generated by an oilfield *i* (*i* = *1*, *2*, ..., *N*) is just the product of unit resource rent and annua production, i.e., $(p_i - c_i)x_i$.

Then, according to the standard NPV method, the asset value of an oilfield *i* (*i* = *1*, *2*, …, *N*) at the beginning of year *t*, $V_i^t$, equals the sum of the flow of future resource rents over $T_i$ years, with each future resource rent being discounted back to the beginning of year *t*:

(1) $$V_i^t = \sum_{\tau=1}^{T_i}[(p_i - c_i)x_i/(1+r)^{\tau}] = (p_i - c_i)x_i \sum_{\tau=1}^{T_i}(1+r)^{-\tau}, \qquad i = 1, 2, \dots, N.$$

Following the 'Bottom-up' approach, the total asset value of the petroleum resources on the continental shelf of the country at the beginning of year *t*, $V_B^t$, can be estimated as:

(2) $$V_B^t = \sum_{i=1}^{N} V_i^t = \sum_{i=1}^{N}\left[(p_i - c_i)x_i \sum_{\tau=1}^{T_i}(1+r)^{-\tau}\right].$$

Note that the letter 'B' has been inserted in the subscript of $V_B^t$ to indicate that the total asset value of petroleum resources on the continental shelf of the country is calculated by using the 'Bottom-up' approach.

Now let us make a permutation for all the *N* oilfields and relabel them such that the following ranking order for the remaining extraction years for all the oilfields on the continental shelf is obtained:

(3) $$T_1 < T_2 < \cdots < T_{N-1} < T_N.$$

In fact, the ranking order as implemented and shown in expression (3) is quite general. For example, if there are two oilfields having the same remaining extraction years, merging the two is always a solution for maintaining the order as shown in expression (3), certainly, the total number of oilfields will be reduced accordingly.

After the permutation and relabelling, the first oil field labelled as '1' has the shortest remaining years for extraction, and the second with label of '2' has the second shortest remaining years for extraction, and so on.

We now extend equation (2) a little bit as:

(4) $$V_B^t = \sum_{i=1}^{N}\left[(p_i - c_i)x_i \sum_{\tau=1}^{T_i}(1+r)^{-\tau}\right]$$

$$= \sum_{i=1}^{N}\left[(p_i - c_i)x_i \sum_{\tau=1}^{T_1}(1+r)^{-\tau}\right] + \sum_{i=2}^{N}\left[(p_i - c_i)x_i \sum_{\tau=T_1+1}^{T_2}(1+r)^{-\tau}\right] + \cdots$$

$$+ \sum_{i=N-1}^{N}\left[(p_i - c_i)x_i \sum_{\tau=T_{N-2}+1}^{T_{N-1}}(1+r)^{-\tau}\right] + \left[(p_N - c_N)x_N \sum_{\tau=T_{N-1}+1}^{T_N}(1+r)^{-\tau}\right].$$

The second identity in equation (4) reveals that from year *t* until the end of $T_1$, counted from the beginning of year *t*, all *N* oilfields will be in operation; but during the $T_2$ period, counted from the beginning of year $T_1$+1, there will be only *N-1* oilfields being in operation, because the first oilfield (labelled of '1') has already been closed during the $T_2$ period. The process goes on until the last period $T_N$ during which only one oilfield (labelled of '*N*') will be in operation, and all the other oilfields have been terminated during the last period of time.

Recall that all the predicted profiles as revealed by equation (4) are based on the information set that is formed at the beginning of year *t*. With this in mind, we can now come back to and discuss a bit further the assumption of constant marginal cost $c_i$ (*i* = *1*, *2*, …, *N*) for each oilfield.

Over time, when an oilfield's marginal cost does increase, then normally new investment in fixed capital in the oilfield is needed, after the new investment, the oilfield in concern can well be considered as a new oilfield with a new, and possibly higher, constant marginal cost for the updated remaining extraction years. By reranking the total oilfields, the expectation process as just described by equation (4) can be maintained. Therefore, the constant marginal cost assumption may not be so restricted as it first looks. Moreover, the similar reasoning can also be applied for dealing with new discoveries of petroleum resources, by treating them as new oilfields within the same model setting.

Now let us turn to the 'Aggregate' approach for estimating the asset value of petroleum resources on the continental shelf of the country, where the total resource rent generated by the petroleum extraction industry is estimated directly instead of by summing up those from individual oilfield. Then an industry-level annual basic price and marginal cost should be modelled.

Consistent with the practice, one possibility is to apply a weighted average of the basic price and the marginal cost of all oilfields, with the weight being given as annual production for each oilfield, then the annual basic price $P^T$ and the marginal cost $C^T$ at the industry level can be defined as:

(5) $$P^T = (\sum_{i=1}^{N} p_i x_i)/(\sum_{i=1}^{N} x_i),$$

(6) $$C^T = (\sum_{i=1}^{N} c_i x_i)/(\sum_{i=1}^{N} x_i).$$

Note that neither the annual basic price $P^T$ nor the annual marginal cost $C^T$ at industry level is independent of future time period (ahead of $t$), because over time some oilfields will be totally depleted and removed from the set of all oilfields of the petroleum extraction industry.

To be more precise and also for the notational simplicity, we can define the industry-level annual basic price in the future (ahead of $t$) periods $T_1$, $T_2 - T_1$, ... $T_{N-1} - T_{N-2}$, $T_N - T_{N-1}$ as:

(7) $$P^{T_1} = (\sum_{i=1}^{N} p_i x_i)/(\sum_{i=1}^{N} x_i)$$

$$P^{T_2} = (\sum_{i=2}^{N} p_i x_i)/(\sum_{i=2}^{N} x_i)$$

...

$$P^{T_{N-1}} = (\sum_{i=N-1}^{N} p_i x_i)/(\sum_{i=N-1}^{N} x_i)$$

$$P^{T_N} = (p_N x_N)/x_N = p_N.$$

The interpretation of equation (7) is as follows: $P^{T_1}$ is the annual basic price faced by the whole petroleum extraction industry for the period from year $t$ to $T_1$, and $P^{T_2}$ is that for the period from $T_1$+1 to $T_2$, and so on.

Using the same logic, the corresponding industry-level annual marginal cost in the future (ahead of $t$) periods $T_1$, $T_2 - T_1$, ... $T_{N-1} - T_{N-2}$, $T_N - T_{N-1}$ can be defined accordingly as:

(8) $$C^{T_1} = (\sum_{i=1}^{N} c_i x_i)/(\sum_{i=1}^{N} x_i)$$

$$C^{T_2} = (\sum_{i=2}^{N} c_i x_i)/(\sum_{i=2}^{N} x_i)$$

...

$$C^{T_{N-1}} = (\sum_{i=N-1}^{N} c_i x_i)/(\sum_{i=N-1}^{N} x_i)$$

$$C^{T_N} = (c_N x_N)/x_N = c_N.$$

If the 'Aggregate' approach for estimating the asset value is followed, the total asset value of petroleum resources on the continental shelf of the country at the beginning of year $t$, $V_A^t$, can be estimated as:

$$(9) \quad V_A^t = \sum_{\tau=1}^{T_N}[(P^{T_i} - C^{T_i})\sum_{i=1}^{N} x_i](1+r)^{-\tau}$$

$$= \sum_{\tau=1}^{T_1}[(P^{T_1} - C^{T_1})\sum_{i=1}^{N} x_i (1+r)^{-\tau}] + \sum_{\tau=T_1+1}^{T_2}[(P^{T_2} - C^{T_2})\sum_{i=2}^{N} x_i (1+r)^{-\tau}] + \cdots$$

$$+ \sum_{\tau=T_{N-2}+1}^{T_{N-1}}[(P^{T_{N-1}} - C^{T_{N-1}})\sum_{i=N-1}^{N} x_i (1+r)^{-\tau}] + \sum_{\tau=T_{N-1}+1}^{T_N}[(P^{T_N} - C^{T_N})x_N(1+r)^{-\tau}]$$

$$= \sum_{\tau=1}^{T_1}[\sum_{i=1}^{N}(p_i - c_i)x_i (1+r)^{-\tau}] + \sum_{\tau=T_1+1}^{T_2}[\sum_{i=2}^{N}(p_i - c_i)x_i (1+r)^{-\tau}] + \cdots$$

$$+ \sum_{\tau=T_{N-2}+1}^{T_{N-1}}[\sum_{i=N-1}^{N}(p_i - c_i)x_i (1+r)^{-\tau}] + \sum_{\tau=T_{N-1}+1}^{T_N}[(p_N - c_N)x_N(1+r)^{-\tau}]$$

$$= \sum_{i=1}^{N}\left[(p_i - c_i)x_i \sum_{\tau=1}^{T_1}(1+r)^{-\tau}\right] + \sum_{i=2}^{N}\left[(p_i - c_i)x_i \sum_{\tau=T_1+1}^{T_2}(1+r)^{-\tau}\right] + \cdots$$

$$+ \sum_{i=N-1}^{N}\left[(p_i - c_i)x_i \sum_{\tau=T_{N-2}+1}^{T_{N-1}}(1+r)^{-\tau}\right] + \left[(p_N - c_N)x_N \sum_{\tau=T_{N-1}+1}^{T_N}(1+r)^{-\tau}\right] = V_B^t.$$

Note that in the left-hand side of the first identity of equation (9), the letter 'A' has been inserted in the subscript of $V_A^t$ to indicate that the total asset value of petroleum resources on the continental shelf of the country is calculated by using the 'Aggregate' approach.

The use is made of equations (5), (6), (7), and (8) by equation (9), and especially, of equation (4) for the last identity in equation (9). Clearly, equation (9) demonstrates that the estimate of the total asset value of petroleum resources on the continental shelf of the country by following the 'Aggregate' approach ($V_A^t$), and that by following the 'Bottom-up' approach ($V_B^t$) coincide under the assumptions made in this paper.

## 2.2. A lemma

Now let us assume that the ranking order of the marginal cost for all oilfields $c_i$ (*i = 1*, *2*, …, *N*) on the continental shelf of the country is as follows:

$$(10) \quad c_1 < c_2 < \cdots < c_{N-1} < c_N.$$

Some discussions are needed here about the assumption as shown in expression (10). Intuitively, it is not easy to justify expression (10), because the shorter the remaining extraction years are for an oilfield, the higher the marginal cost of the oilfield in concern will be. But this argument holds in general for an individual and specific oilfield, especially when this specific oilfield approaches its closedness, as also being discussed in the subsection 2.1 where we show that the model setting is still valid even if an oilfield's marginal cost does increase over time.

When comparing the marginal cost among different oilfields as shown by expression (10), however, there might exist other important offsetting factors playing here. One offsetting factor is that oilfields with lower marginal cost are often easily to be found and extracted earlier, newly discovered oil fields, so with relatively longer remaining extraction years, will also have relatively larger marginal cost than previously discovered oilfields that now have shorter remaining extraction years.

The answer to the question about which factors are stronger than others is purely an empirical issue. Therefore, we leave this issue for the moment and just assume that expression (10) is valid.

With the assumption of expression (10), the following lemma holds:

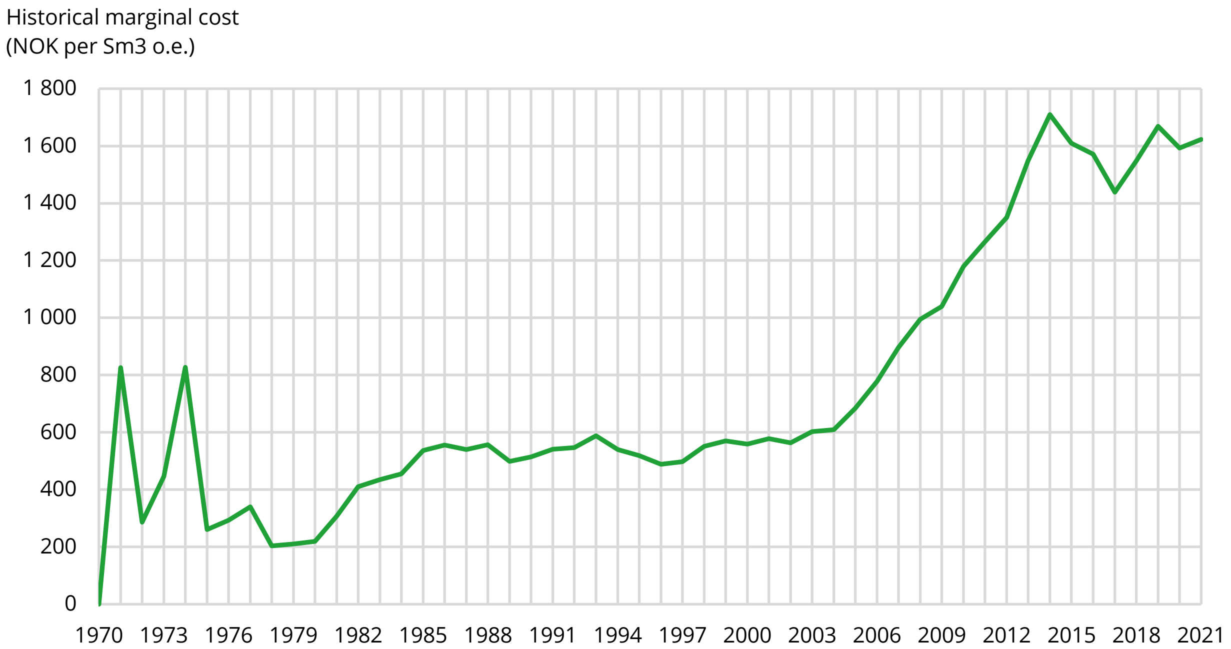
$$(11) \quad C^{T_1} = (\sum_{i=1}^{N} c_i x_i)/(\sum_{i=1}^{N} x_i) < C^{T_2} = (\sum_{i=2}^{N} c_i x_i)/(\sum_{i=2}^{N} x_i) < \cdots$$

$$< C^{T_{N-1}} = (\sum_{i=N-1}^{N} c_i x_i)/(\sum_{i=N-1}^{N} x_i) < C^{T_N} = c_N.$$

The proof of the lemma, i.e., expression (11), is presented in Appendix A.

The inequalities as shown in expression (11) indicate that the industry-level marginal cost $C^{T_i}$ will increase stepwise over time in the future, although the marginal cost $c_i$ (*i* = *1*, *2*, …, *N*) is constant for each individual oilfield *i* (*i* = *1*, *2*, …, *N*).

**Figure 2.1 Estimated marginal cost in Norwegian petroleum extraction industry (in current prices, 1970-2021)**




Source: Authors' own calculations based on data from https://www.norskpetroleum.no/ and www.ssb.no, see Liu (2023a).

Figure 2.1 displays the estimated historical marginal cost in current prices in the Norwegian petroleum extraction industry over the period 1970-2021. The marginal cost is measured as NOK per standard cubic metre oil equivalent ($Sm^3$ o. e.). As shown, the industry-level marginal cost, except for the period of early 1970s, has been increasing in general.

The observed historical trends in Norway as displayed in Figure 2.1 are in line with those inequalities as shown by expression (11), which are derived based on the assumption as shown by expression (10) in the model as described in this section. But it should be noted that the inequalities as shown by expression (10) are not a necessary condition, rather, they are only a sufficient condition for expression (11) to be valid, implying that there might exist other sufficient conditions for expression (11) to be valid.

Therefore, even if the expression (10) does not hold, the empirical modelling of the predicted profile of the industry-level marginal cost can be based on the historical trends in Norway, as what has been applied in Liu (2016, 2023a), which is also in accordance with the model setting in this paper.

More importantly, the model as presented in this paper demonstrates that under some simple and practical assumptions, the estimates of the asset value from the 'Aggregate' approach and the 'Bottom-up' approach may coincide with each other.

In other words, it might be reasonable to make estimates of the asset value of petroleum resources on the Norwegian continental shelf by either following the 'Aggregate' approach or following the 'Bottom-up' approach. Therefore, it seems that the choice between the two approaches for the estimation is just a practical issue that hinges to a large extent on the data quality applied by each approach.

# 3. Assessment of feasibility

In this section, an assessment will be made as regards whether it is feasible to follow the 'Bottom-up' approach by first estimating the asset value of petroleum resources from the oilfield level, and then summing up the estimated oilfield results to arrive at an estimate for the asset value of total petroleum resources on the Norwegian continental shelf.

By means of the 'Aggregate' approach, the asset value of total petroleum resources on the Norwegian continental shelf was estimated in Liu (2016, 2023a) by using primarily the NNA data, as recommended by the SEEA-CF. Formally, annual total resource rent generated by the entire petroleum extraction industry [3] was calculated by using annual NNA data and following the procedure as listed in Table 3.1, which is a direct copy of Table 5.5 in the SEEA-CF.

**Table 3.1 Deriving resource rent from the SNA measures**

| **Output** (sales of extracted environmental assets at basic prices, includes all subsidies on products, excludes taxes on products) |
|---|
| ***Less*** Operating costs |
| Intermediate consumption (input costs of goods and services at purchasers' prices including taxes on products) |
| Compensation of employees (input costs for labor) |
| Other taxes on production plus other subsidies on production |
| ***Equals Gross operating surplus*—SNA basis** |
| ***Less*** Specific subsidies on extraction |
| ***Plus*** Specific taxes on extraction |
| ***Equals*** **Gross operating surplus—for the derivation of resource rent** |
| ***Less*** User costs of produced assets |
| Consumption of fixed capital (depreciation) + return to produced assets |
| ***Equals*** **Resource rent** |
| Depletion + net return to environmental assets |

Source: Table 5.5 in United Nations *et al*. (2014)

To maintain the internal consistency, following the 'Bottom-up' approach to estimate the asset value of petroleum resources on the Norwegian continental shelf requires that the same procedure as listed in Table 3.1 should be followed also at the oilfield level, implying that all the items as listed in Table 3.1 should be ready for each oilfield. In other words, it is each and every oilfield, rather than the entire petroleum extraction industry, that should be treated as a production unit. The feasibility assessment will be undertaken with this in mind.

## 3.1. Oilfield as establishment

An oilfield is one or several discoveries combined on the Norwegian continental shelf. As of December 31, 2022, there are in total 98 oilfields either in active production (93 fields) or with

[3] The petroleum extraction industry is coded as '23060' in the NNA, and as '06.' in the SN2007, the Norwegian Standard Classification for Industry, which is based on NACE Rev.2.

approved development plans, located in the North Sea, the Norwegian Sea, and the Barents Sea on the Norwegian continental shelf.

Regulated by law, the Norwegian government awards petroleum production licences to groups of companies, normally through various licensing rounds. A production licence grants exclusive rights to exploration, exploration drilling, and production of petroleum in the area covered by the licence, such as an oilfield. Then the licensees become the owners of a share of the oil and gas produced by the oilfield, proportional to their share of the ownership.

Meanwhile, the government designates an operator for the joint venture, and this company is responsible for the operational activities of the oilfield authorised by the licence and for reporting on behalf of all the licensees the information about production, income, cost, and investment occurred in the oilfield to the Norwegian government.[4]

Therefore, an oilfield on the Norwegian continental shelf can be practically regarded as a local kind of activity unit for production of petroleum products, or an establishment as defined in the SNA; but different from the general rule where each establishment belongs to one and only one company, an oilfield is usually owned by a number of companies, in term of licensees.

## 3.2. Main data sources

The Oil Statistics (hereafter OS) and the Investment Statistics (hereafter IS) are two main statistical data sources for compiling the NNA as regards the petroleum extraction industry. The OS is used for calculating production and intermediate consumption, while the IS is used for constructing investment series, together with other data sources, such as those from foreign trade statistics, energy statistics etc.

In general, the OS and the IS are of high quality, but there are differences in the concepts applied by the NNA and those in the OS as well as the IS, therefore, some adjustments should be made in order to arrive at the estimates consistent with the NNA concepts. Some of these differences will be discussed in the following for the purpose of this paper, but for a more comprehensive overview of the detailed differences and other information, reference should be made to Tjønneland (2018).

## 3.3. Output at basic prices

For each oilfield, the production of petroleum products in terms of both quantity and value is reported to the Norwegian government and thus available, but the value of raw oil is calculated by the so-called ‘norm prices’ which are set by the government for tax purposes,[5] and are not necessarily in accordance with the price concepts applied in the NNA.

To derive the basic prices for raw oil and natural gas for the entire petroleum extraction industry in the NNA, the corresponding export prices (FOB) [6], considered as purchasers’ prices, are corrected for transport margins which are tariffs paid for using the domestic oil pipeline and gas transportation system. For LNG (Liquified Natural Gas) and NGL (Natural Gas Liquids), such corrections are not made.

If the output at basic prices for raw oil and natural gas for each oilfield is to be estimated for implementing the ‘Bottom-up’ approach by following the procedure as listed in Table 3.1, the total transportation margins for the entire extraction industry should be allocated to each oilfield. But this allocation is not easy, because, for instance, not only the quantity produced by, but also the

[4] For more information, please refer to the website of the Norwegian Petroleum Directorate at www.npd.no.
[5] See https://www.regjeringen.no/en/topics/energy/oil-and-gas/petroleum-price-board-and-the-norm-price/id661459/
[6] Exports of goods are valued free-on-board (FOB), meaning that they are valued at the exporter’s customs frontier.

geographic location of, each oilfield may jointly determine the transportation cost, but in what mechanism, it is not very clear.

## 3.4. Intermediate consumption

Although the output from each oilfield is divided into different petroleum products such as raw oil, natural gas, NGL, separate intermediate consumption for each and every one of the petroleum products cannot be derived from the total intermediate consumption reported by each oilfield.

As mentioned, there are also some differences between the intermediate consumption reported by oilfields and what should be applied in the NNA.

### FISIM

FISIM (Financial intermediation services indirectly measured) is not reported by each oilfield, and the total FISIM used by the entire petroleum extraction industry is calculated in the NNA by applying other method and data. To allocate the total FISIM across oilfields is not easy.

### Electricity consumption

In the NNA, other data sources than the OS are employed for calculating the total electricity consumption for the entire petroleum extraction industry. It is not easy to allocate the total electricity consumption across oilfields either.

### Insurance premiums

Insurance premiums reported by oilfields are actual premiums payable by policy holders to obtain insurance cover during the accounting period. In order to obtain net insurance premiums to be used in the NNA, the premium supplements payable out of the property income attributed to policy holders have to be added, and the service charges of insurance enterprises arranging the insurance have to be deducted.

Again, the calculation is carried out for the entire petroleum extraction industry only. To allocate the total to each oilfield may not be straightforward either.

## 3.5. Costs of labour

In 2015, a new data reporting system (A-ordning) [7] was introduced in Norway with the purpose of simplifying and coordinating the reporting of information by employers to various government institutes. Submitted electronically and at least once a month, employers will provide information concerning income, employment circumstances, payroll withholding tax deductions, attachment of earnings concerning their employees, the company's employer's national insurance contributions, and financial activity tax.

The system of A-ordning serves as one of the primary data sources for compiling labour costs and employment for industries in the NNA, including the petroleum extraction industry. In addition, as one of the central and fundamental data sources, it is also used for compiling a series of quarterly and annual databases at Statistics Norway (such as industry statistics, labour cost statistics, etc).

Moreover, information from A-ordning are used for processing cases concerning e.g., sick pay, unemployment benefits, etc. by the Norwegian Labour and Welfare Administration, and for calculating e.g., tax returns, tax assessments, etc. by the Norwegian Tax Administration.

[7] A-ordning (in Norwegian) means, word by word, A-arrangement.

Although labour costs are reported by each oilfield in the OS, they are not necessarily of the same quality as those constructed by means of A-ordning. If the 'Bottom-up' approach is followed, the total labour costs constructed by using A-ordning for the entire petroleum extraction industry has to be allocated across oilfields, but it is very hard, because among others, there are no requirements for the enterprises to report employees per oilfield in the A-ordning, rather, reporting is only required for the offshore activities as a whole.

Given the current organisational structure of oilfields as mentioned in the subsection 3.1, there is no guarantee that the source data reported by each oilfield is the same as those applied by A-ordning. But the application of A-ordning ensures not only the comparability of labour costs estimates across industries in the NNA, but also the consistency with many other types of labour and employment related statistics compiled at Statistics Norway and beyond.

## 3.6. Costs of produced capital

In the NNA, net capital stock and capital depreciation (consumption of fixed capital) cross-classified by asset type and industry are estimated by using the Perpetual Inventory Method (PIM), based on the time series of investment data (Todsen, 1997).

From the IS, the investment series can be obtained for each oilfield, the estimation of net capital stock and consumption of fixed capital seems not to be a problem by applying the PIM model. However, there exist some definitional and other differences between the IS and the NNA.

### Area fees

The IS includes area fees reported by oilfields as the investment expenditure, while the NNA excludes them, because according to the principles of the SNA, they are to be counted as a tax and not an investment.

If the area fees paid by oilfields are considered as some kind of 'specific taxes' meaning that they are 'specific' to the petroleum extraction activities, then area fees should be included in the resource rent calculations by following the procedure as listed in Table 3.1. In Liu (2023a), the resource rents generated by the petroleum extraction industry are calculated both with and without the area fees.

### R&D

The IS does not include investments in R&D in its statistics. Investment in R&D in the Norwegian economy are calculated by using other sources and methods (Sørensen, 2016).

Since own-account investment of R&D should also be accounted as output production, missing R&D investment in the IS will lead to downward bias for the estimate of the output.

To allocate the estimated total R&D investment, both the own-account production and the purchased R&D, in the entire petroleum extraction industry to oilfields is not an easy task.

### Used capital

When applying the PIM model for estimating net capital stock and capital depreciation, an implicit assumption made is that the investment should be measured at the 'as new' price. However, under the circumstances where the actual investment involves transactions in used assets, a problem arises (e.g., Schreyer, 2009).

Suppose, for example, an oilfield sells a used asset to another oilfield, the seller will report the sale of the used asset at its current market price but not at the 'as new' price which is required by the PIM model. This means that *ceteris paribus*, the investment reported by the seller (its acquisitions less disposals of assets) will be too large for use in the PIM model because its disposals are valued at the (low) market price instead of at (high) 'as new' price.

At the same time, the oilfield purchasing the used asset will report its acquisition of the used asset from the seller at the current market price which is lower than the 'as new' price required by the PIM model. Other things being equal, the purchaser's reported investment (its acquisitions less disposals) will be too small for use in the PIM model.

In the IS, investments are recorded as new investments, although sale and buy of the used assets among companies are anecdotally not uncommon in the petroleum extraction industry.

Continuing the example, the bias caused by the way that the two oilfields report transactions in a used asset will cancel out if their records are consolidated because the overstatement of the seller's reported investment is exactly offset by the understatement in purchaser's reported investment.

Consequently, when transactions of used assets are involved, activity breakdowns should be modest. In this sense, if the PIM model is applied for measuring net capital stock and capital depreciation, the choice seems to be in favour of the 'Aggregate' approach rather than the 'Bottom-up' approach.

Certainly, when oilfields on the Norwegian continental shelf have transactions of used assets with enterprises resident in other countries, the estimate of investment for the entire Norwegian petroleum extraction industry will be biased following the same reasoning, but dealing with this issue is another story beyond the purpose of this paper.

## 3.7. Costs related to terminals

In Norway, there are some onshore terminals that are associated with the petroleum extraction industry. These terminals are treated as part of the petroleum extraction industry in the NNA, because the typical activity at these terminals consists of the refining, fractionation and processing of raw oil and natural gas, and arguably, this activity is integrated into the petroleum extraction industry in that the terminal operations help give the petroleum products their final form and value.

Further, production value is not attributed to terminal operations in the NNA. The reason for doing this is that the production activities of the terminals are considered a direct internal supply to the extraction companies, and that the terminal activities do not produce anything other than that they only contribute to giving the petroleum products their final value. For the same reason, the production costs at the terminals are handled as product inputs in the petroleum extraction industry as a whole.

If the 'Bottom-up' approach is followed, the total costs related to the terminals should be allocated to each oilfield, including not only intermediate costs, but also costs of labour and capital, otherwise the estimated output for the total industry is upward biased. However, how to make this allocation in a reasonable way is not very clear yet.

## 3.8. Time series

Over time, there have been a number of changes occurred to the OS and the IS data sources in terms of changes of collection method, definitions, classifications, and methodologies applied (see Skullerud, 2019). There were also organizational changes in that compilation and maintenance of the data sources were moved from one division to the other at Statistics Norway.

Although efforts at Statistics Norway have been made for constructing consistent historical statistics for oil and gas extraction activities, breaking down the constructed time series data for the petroleum extraction industry by oilfields is not straightforward.

Therefore, it is not easy to construct a time series dataset at the oilfield level, that not only should be consistent with that from the level of the entire petroleum extraction industry, but also should be consistent over time.

# 4. Concluding remarks

Generally speaking, two approaches are available for estimating the asset value of petroleum resources on the Norwegian continental shelf by following the internationally recommended NPV method. The first is an 'Aggregate' approach that considers the entire petroleum extraction industry as one single production unit and calculates the resource rent and the asset value accordingly, and the second is a 'Bottom-up' approach that estimates the resource rent and the asset value first from the oilfield level and then sums up the oilfields' results to arrive at an aggregate one.

This paper aims to assess both the necessity and the feasibility of applying the 'Bottom-up' approach from the oilfield level. Assessment of necessity is implemented by means of a simple model, which demonstrates that under some modest and practical assumptions, the estimates by following the 'Aggregate' and 'Bottom-up' approaches may coincide with each other, implying that either of the two approaches can be equally applied in practice. Thus, empirical application of the two approaches depends to a large extent on the data quality used by each approach.

To apply the 'Bottom-up' approach from the oilfield level for estimating the asset value of petroleum resources on the Norwegian continental shelf, data with at least the same quality as those at the industry level should be readily available. Assessment of feasibility is therefore carried out by a thorough investigation on the availability of such quality data at oilfield level.

The conclusion is that data needed for applying the 'Bottom-up' approach that are in accordance with the NNA concepts and of at least equivalent quality as those applied at the industry level are hard to be obtained, at least at present. Certainly, depending on the analysis purposes, quality data at the oilfield level are needed and have to be prepared, for example, under circumstances where microeconomics analyses specifically at oilfield level are to be conducted. However, such analyses are clearly beyond the main purpose of this paper.

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# Appendix A: Proof of Lemma

Lemma: Given $c_1 < c_2 < \cdots < c_{N-1} < c_N$, the following inequalities hold:

$$C^{T_1} = (\sum_{i=1}^{N} c_i x_i)/(\sum_{i=1}^{N} x_i) < C^{T_2} = (\sum_{i=2}^{N} c_i x_i)/(\sum_{i=2}^{N} x_i) < \cdots$$

$$< C^{T_{N-1}} = (\sum_{i=N-1}^{N} c_i x_i)/(\sum_{i=N-1}^{N} x_i) < C^{T_N} = c_N.$$

Proof: Picking up any one inequality among the above to-be-proved *N-1* inequalities gives:

$$C^{T_j} = (\sum_{i=j}^{N} c_i x_i)/(\sum_{i=j}^{N} x_i) < C^{T_{j+1}} = (\sum_{i=j+1}^{N} c_i x_i)/(\sum_{i=j+1}^{N} x_i), \quad 1 \le j < N.$$

It can be rewritten as:

$$C^{T_j} = (c_j x_j + \sum_{i=j+1}^{N} c_i x_i)/(x_j + \sum_{i=j+1}^{N} x_i) < C^{T_{j+1}} = (\sum_{i=j+1}^{N} c_i x_i)/(\sum_{i=j+1}^{N} x_i), 1 \le j < N.$$

Rearranging the above inequality yields:

$$c_j x_j \sum_{i=j+1}^{N} x_i + (\sum_{i=j+1}^{N} c_i x_i)(\sum_{i=j+1}^{N} x_i) < x_j \sum_{i=j+1}^{N} c_i x_i) + (\sum_{i=j+1}^{N} c_i x_i)(\sum_{i=j+1}^{N} x_i),$$

$1 \le j < N.$

Removing the same items from the two sides of the inequality, using the fact of $x_j > 0$, and rearranging the resulted expression gives rise to:

$$\sum_{i=j+1}^{N} c_j x_i < \sum_{i=j+1}^{N} c_i x_i, \quad 1 \le j < N.$$

Clearly, the last inequality holds since $c_j < c_i$ is true for $j < i$.

Q.E.D.