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Measuring the asset value of petroleum resources in Norway

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Preface

This document presents the experimental work for measuring the asset value of petroleum resources on the Norwegian continental shelf over the period 1970-2021 by means of the net present value (NPV) method. It is the third 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 project aims to compile the experimental estimates of Norwegian petroleum resources as a non-financial asset, in accordance with the international statistical standards, and with the relevant recommendations given in the Guidance Notes by United Nations' Task Teams working for updating the System of National Accounts (SNA).

In addition, the project can serve as an early-implementation exercise prior to the final approval of the updated SNA in 2025. The outcomes, including knowledges gained and lessons learned, of the project can be well utilised to facilitate preparing for the adoption of the envisaged new SNA as international standards for countries worldwide, and of the subsequently revised European System of Accounts (ESA) as regional standards for EU member states and other European countries.

Given the experimental character of this project, the authors wish to make it clear that the views expressed in this experimental work are their own opinions. They are not the official views of Statistics Norway and should not be interpreted as such in any sense.

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Lasse Sandberg

Abstract

From an accounting perspective, this paper presents formally the detailed implementation procedure by applying the net present value (NPV) method to measuring the asset value of Norwegian petroleum resources for the period 1970-2021. A variety of concrete implementation issues are addressed, and alternative solutions are suggested accordingly.

By means of the residual value method, *ex-post*, or historically realized, resource rents are estimated for the period 1970-2020, from which a long-term average real unit resource rent is derived and then used as a predicted future real unit resource rent. Together with a predicted future production profile, at the beginning of 2021, the asset value of Norwegian petroleum resources is estimated in both current and constant prices for 2021. Using the calculated 2021 asset value and based on *ex-post* annual resource rent for the period 1970-2020, the asset value at the beginning of each year during the period 1970-2020 is also estimated.

Sensitivity analysis is conducted with respect to the choice of rate of return to produced capital and discount rate, indicating that the estimated asset value is more sensitive to the choice of discount rate than to that of rate of return. For each chosen rate of return, when the discount rate increases by a constant margin, the estimated asset value decreases, but the marginal effect is decreasing. In addition, the differences by using the different rate of return are also decreasing.

The estimation of petroleum asset value by applying the NPV method is based on a number of assumptions, leading to uncertainties to the final estimates. This observation justifies the need for further international corporation in harmonizing the way the key assumptions are made for such compilations.

Although the final decision about the compilation of petroleum asset value as official statistics is still pending in Norway, for example, as regards the choice of specific and detailed implementation procedure, including the choice of rate of return and discount rate, a number of preferences and recommendations drawn from this paper are tentatively given in the end.

Contents

1. Introduction

Petroleum resources on the Norwegian continental shelf play a vitally important role in the Norwegian economy and are valuable for the financing of a well-functioning welfare state in Norway. For instance, the petroleum extraction industry[1] contributes, either directly or indirectly, but substantially to the entire Norwegian economy in terms of employment created, value added generated, investments conducted, export delivered, and government revenues rendered.[2]

In the current Norwegian National Accounts (NNA), extracted petroleum products, such as crude oil, natural gas, natural gas liquids (NGL), and condensate, are recorded as output in the production account of the petroleum extraction industry, but petroleum resources by its own right has not yet been registered as non-financial asset in the balance sheet account.

Following the latest international statistical standards, namely, the *System of National Accounts 2008* (hereafter 2008 SNA) (United Nations *et al*., 2009) and the *European System of Accounts* (hereafter ESA 2010) (Eurostat, 2013), according to which the NNA is compiled [3], petroleum resources as part of 'Mineral and energy reserves (AN.212)' should be incorporated into non-produced non-financial asset (AN.2) in the balance sheet account, although reporting the estimated results to Eurostat is not compulsory at present (Eurostat, 2014).

Apparently, a crucially important linkage is missing between petroleum resources *in situ* as a concept of stock (capital or asset) and extraction of petroleum resources as a concept of flow (capital services) in the current NNA. Moreover, when monitoring the change of an incomplete national wealth over years with valuable petroleum resources unaccounted, it is hardly possible to send the right signal for policymakers to make sensible sustainability assessment.

As is well known, petroleum resources are not only valuable resources but also fossil fuels, the use of which in economic activities is bound to generate greenhouse gas emissions, leading to the conundrum of global warming. To address the pending global issue, and more importantly, to help achieve environmental as well as economic sustainability, a good accounting of petroleum resources, in terms of both monetary values and physical quantities, is indispensable.

On an international arena, the call for an integration of environmental and economic accounting has been repeatedly voiced by the academia, the policymakers, the media, and the public more generally. As a response, another international statistical standard, i.e., the *System of Environmental-Economic Accounting 2012 – Central Framework* (hereafter SEEA-CF) (United Nations *et al*., 2014) provides useful recommendations as regards how to measure the asset value of natural resources.

Petroleum resources *in situ* are rarely bought and sold in market,[4] therefore, the net present value (NPV) method has to be applied which estimates the asset value as the sum of discounted future returns based on the information available at the accounting point. In both 2008 SNA and ESA 2010, the NPV method is recommended in a broad sense for the valuation of mineral and energy resources, while in SEEA-CF, more detailed and concrete implementation procedures are also given.

[1] The petroleum extraction industry is coded as '23060' in the Norwegian National Accounts, and as '06.' in the SIC 2007, the Norwegian Standard Industrial Classification 2007, which is based on NACE Rev.2.
[2] See various statistics in the Norwegian National Accounts and Government Finance Statistics published by Statistics Norway at: https://www.ssb.no/en/statbank
[3] Under the European Economic Area (EEA) Agreement, it is obligatory for Norway, though not an EU member country, to compile the NNA according to ESA 2010 and transmit the required statistics to Eurostat, the statistical office of the EU.
[4] Ddespite a few information about license transaction (see e.g., https://www.finansavisen.no/nyheter/energi/2013/05/det-norske-kjoeper-og-selger-lisenser?zephr_sso_ott=JklLBu), there is no organized market for trading the licenses/contracts in Norway.

Recently, during the course of updating 2008 SNA, extending the current 2008 SNA to incorporate aspects of SEEA-CF was suggested, for example, as regards the valuation of mineral and energy resources. It was recommended that more clarifications be added with respect to the application of the NPV method by explicitly referring to Chapter 5 in SEEA-CF; more explanations be given on dealing with the specific compilation issues, including the treatment of volatility due to fluctuations of commodity prices, and the choice of some key parameters to be used in the NPV method etc. (Fixler, 2022).

In Norway, accounting for natural resources in general and petroleum resources in particular has a long history ever since 1970s, and measuring the asset value of petroleum resources as part of Norwegian national wealth has been, though not regularly, carried out in various research projects (see e.g., Brekke *et al*., 1989; Aslaksen *et al*., 1990; Lindholt, 2000; Greaker *et al*., 2005; Brunvoll, *et al*., 2012; Norwegian Ministry of Finance, 2012a; Liu, 2016).[5]

The detailed methodologies that have been applied in these studies, however, vary to some extent, and even if some studies were conceptually consistent with 2008 SNA and ESA 2010 or even SEEA-CF, the choice of detailed assumptions and key parameters for valuation had yet to be harmonised, otherwise comparison analysis either over time or across countries is, if not impossible, rather challenging.

The primary objective of this paper is to compile and harmonise as much as possible the experimental value estimates of Norwegian petroleum resources as an asset, in accordance with the international statistical standards, as well as with the recommendations given in the relevant Guidance Note by UN Task Teams working for SNA updating (e.g., Fixler, 2022). In addition, it is hoped that the presented results in this paper will fulfil one of the specific objectives of an ongoing project at Statistics Norway ('Valuation of petroleum resources in Norway'), which is partly financed by Eurostat (Project number and acronym: 101122519, 2022-NO-SNA-UPDATE).

Moreover, the estimation practice as documented in this paper may be regarded as an early-implementation exercise prior to the final approval of the updated SNA which is planned in 2025 and of the following update of the ESA in Europe, as well as the ESA Data Transmission Program (TP). As a part of the EEA agreement, Norway is obliged to follow the ESA and reports statistical data to Eurostat following the ESA TP. Thus, another purpose of this exercise is to explore the feasibility of implementing the international recommendations based on available national data and circumstances and to find the best practical solutions and adaptions, and at the same time, highlighting various uncertainties related to the estimation.

Therefore, whatever outcomes from the experimental estimation as documented in the paper, including knowledges gained and lessons learned, can well be utilised to facilitate the preparation for the adoption of the envisaged new SNA as international standard for countries worldwide, and of the subsequently revised ESA as regional standards for EU member states and other European countries.

The rest of the paper is structured as follows. In Section 2, different methods for asset valuation in general are first introduced, then the specific NPV method, suitable for measuring the asset value of petroleum resources, is formally formulated from an accounting perspective.

Section 3 discusses briefly various methods for estimating resource rent in practice, followed by more discussions about a number of specific compilation issues appeared when the residual value

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[5] For a brief overview on wealth accounting practices and its relationship with the work for natural resource accounting in Norway, see Liu (2013).

method is to be applied. In this section, estimated historical resource rents for the period 1970-2020 are finally presented. In Section 4, based on the revealed historical pattern of the real unit resource rent, together with predicted future production profile, the NPV method is implemented. The estimated asset values of Norwegian petroleum resources for the period 1970-2021, in both current and constant prices and conditional on the choice of discount rate, are reported and discussed. Section 5 concludes the paper.

Before moving forward, it is worth mentioning at this stage that the focus of this paper is on annual accounts, therefore, unless stated otherwise, all the accounting flows and the associated parameters referred in this paper are per annum.

2. Methodology

2.1. Methods available for asset valuation

An asset or capital can be used for more than one accounting period (such as one calendar or fiscal year) and it is the expected flows of benefits derived by holding or using the asset over its service life that lay the foundation and thus enable various economic agents to attach an economic value on the asset in concern.

If market exists for the asset, the observed market prices can be directly used for valuation and for the purpose of establishing balance sheet account, the asset should be valued as if it were being acquired on the date to which the estimate of the stock relates, usually at the beginning or the end of an accounting period. This is the first and ideal method for asset valuation that may be applied to some, but not all types of capital, such as most financial assets, and some frequently transacted transport equipment, e.g., either new or used cars and trucks.

In cases where no market transactions take place in the recent past, an effort has to be made to estimate what the prices would be if the asset were to be traded on the date to which the balance sheet is to be compiled. One option is to apply the written-down replacement cost which equals the acquisition price of an equivalent new asset deducted by the accumulated capital depreciation over time. As a second method for asset valuation, the written-down replacement cost serves as a reasonable approximation of what the market prices would be if the asset were for sale.

If no market exists for an asset, such as the assets formed through own account production for own final use, as well as the assets of some kind of unique characteristics and thus no equivalent or even similar counterpart can be found in relevant market, total production costs may be used for approximating the market prices of the asset.[6] The use of total production costs is the third method available for the valuation of assets.

For many types of environmental assets, such as the petroleum resources which are the focus of this paper, there are, if at all, very limited market transactions or set of acquisition prices for the resources *in situ* that would permit the application of the first two valuation methods.[7] Moreover, the third method by using total production costs cannot be applied either in that petroleum resources come into existence by nature, in other words, in ways other than through process of production that is defined in the national accounts (see e.g. United Nations *et al*., 2009; Eurostat, 2013).

As just mentioned, the market value of the petroleum resources *in situ*, which is a stock concept, is seldom observed in reality,[8] but the buying and selling information for extracted petroleum products, which is a flow concept, are usually available, and it is the latter information (flows) that can be used for making estimation of the value of the former (stock), by means of the NPV method, which is the fourth method for the valuation of assets.

Although the four practical methods for asset valuation vary from each other, they essentially share a common theoretical framework in which the fundamental relationship between capital stock and the associated flows are maintained: i.e., in equilibrium, the stock value of an asset is equal to the discounted stream of future rental payments for capital services that the asset is expected to yield,

[6] Note that total production costs should include a return to other produced capital that are used for the production of the asset in question, because the return reflects an interest cost that occurs if money is borrowed to purchase the produced capital or the implicit opportunity cost of the equity capital that is tied up in the purchase.
[7] There are exceptions, for example, the market transaction information may sometimes exist for a piece of land.
[8] See footnote 4.

an insight that can be traced back at least to Walras (1874) and Böhm-Bawerk (1888). A modern formulation of this framework for capital measurement has been developed by, among others, Jorgenson (1963, 1989), Christensen and Jorgenson (1969, 1973), Diewert (1974), Hulten (1990), Diewert and Lawrence (2000), Diewert and Schreyer (2008).

2.2. The net present value (NPV) method

The NPV method, also referred to as the discounted value of future returns method, uses projections made at the accounting point to generate a time series of expected returns. With the assumption that returns earned in the current period are worth more to the extractor than returns earned in the future, the stream of expected returns is discounted to reflect the value that a buyer would be prepared to pay for the asset in the current period (United Nations *et al.*, 2014).

For the petroleum resources, the returns are usually defined by using the concept of resource rent, which is best considered to be the surplus value accruing to the extractor or user of the petroleum resources, calculated after all costs and normal returns to produced capital used for extraction have been taken into account (e.g. United Nations *et al*., 2009, 2014; Eurostat, 2013).

Formally, for making estimate of the value of an asset by applying the NPV method, the following equation is applied:

(1) $$V^{tB} = \sum_{\tau=1}^{T^{tB}}[NR^{t+\tau-1}/(1+\delta_t)^{\tau}] \text{ ,}$$

where V^{tB} is the to-be-estimated asset value at the beginning of time period (such as a year) *t*, T^{tB} is the expected number of remaining periods of extraction which varies over time and thus depends on *t*. Note that both V^{tB} and T^{tB} are indexed by the superscript with the capital letter 'B', simply to indicate explicitly that the expectation is formed at the *Beginning* of the time period *t*.

$NR^{t+\tau-1}$ (τ = 1, 2, ..., T^{tB}) is the nominal value of expected future resource rents and the projected time profile of the resource rent $\left\{NR^{t}, NR^{t+1}, \dots, NR^{t+T^{tB}-1}\right\}$ corresponds to the sequence of resource rents generated during the time period *t*, *t+1*, ..., *t+*T^{tB}*-1*. δ_t is a nominal discount rate valid over time period *t*, but not necessarily constant over time.

In equation (1), the expected future resource rent accrued during each future time period $NR^{t+\tau-1}$ is implicitly assumed to be paid at the end of the corresponding period, despite the accounting convention that stocks are usually measured at either the end or the beginning of an accounting period while the associated flows should be measured over the corresponding accounting period, often approximated to be at the middle of the period.

However, the end-of-period payment of resource rent is not an essential assumption in the modelling described in the paper, and the payment could be assumed to be made at the middle of each time period, but only with extra presentational complexity being involved and with no impact, however, on the underlying reasoning applied here (see e.g. Liu, 2024).

Following equation (1), the asset value at the beginning of time period *t* is estimated as the sum of the expected future resource rents, with each being discounted back to the beginning of the period *t*. For example, the resource rent generated during the first period (counted as starting from the beginning of the period *t*), NR^{t}, which is paid at the end of period *t*, should be discounted back to the beginning of the period *t* by multiplying the discount factor $(1+\delta_t)^{-1}$; if δ_t is further assumed to be constant, the resource rent generated during the second period, NR^{t+1}, which is paid at the end of period *t+1*, should be discounted back to the beginning of the period *t* by multiplying the discount factor $(1+\delta_t)^{-2}$, and so on.

At the beginning of period t, a future production or extraction profile in physical quantity $X^{t+\tau-1}$ (τ = 1, 2, ..., T^{tB}) is usually expected as is the case in Norway, then an expected nominal unit resource rent, $UR_N^{t+\tau-1}$, can be defined as:

(2) $$UR_N^{t+\tau-1} = NR^{t+\tau-1} / X^{t+\tau-1}, \tau = 1, 2, ..., T^{tB}.$$

Suppose the expected nominal unit resource rent $UR_N^{t+\tau-1}$ evolves in line with an expected general rate of inflation during the time period t, ρ_t, such that the following relationship holds:

(3) $$UR_N^{t+\tau-1} = UR_R^*(1 + \rho_t)^\tau, \tau = 1, 2, ..., T^{tB},$$

where UR_R^* is the expected real unit resource rent, assumed to be constant over the future time periods.

Sometimes, UR_R^* is set as equal to the real unit resource rent generated in the last year, based on the idea that the last period situation will continue without significant change in the future, then $UR_R^* = UR_R^{t-1}$.

More often, UR_R^* is set as equal to some kind of average over the previous years, such as a 3-eyar or 5-year average, with the purpose of smoothing out as much as possible the volatility of generated resource rent observed in the past.[9]

Note that ρ_t depends on t but is not necessarily constant, an assumption similar to what is made to δ_t.

Given equations (2) and (3), an expected real resource rent $RR^{t+\tau-1}$ corresponding to the expected nominal resource rent $NR^{t+\tau-1}$ as defined in equation (1) can be defined as:

(4) $$RR^{t+\tau-1} = UR_R^* X^{t+\tau-1} = NR^{t+\tau-1}/(1 + \rho_t)^\tau, \tau = 1, 2, ..., T^{tB},$$

Inserting equations (2), (3), and (4) into equation (1) and reorganizing it yields:

(5) $$V^{tB} = \sum_{\tau=1}^{T^{tB}}[NR^{t+\tau-1}/(1 + \delta_t)^\tau] = \sum_{\tau=1}^{T^{tB}}[UR_N^{t+\tau-1} X^{t+\tau-1}/(1 + \delta_t)^\tau]$$

$$= \sum_{\tau=1}^{T^{tB}}[UR_R^* X^{t+\tau-1}(1 + \rho_t)^\tau/(1 + \delta_t)^\tau] = \sum_{\tau=1}^{T^{tB}}[RR^{t+\tau-1}(1 + \rho_t)^\tau/(1 + \delta_t)^\tau]$$

$$= \sum_{\tau=1}^{T^{tB}}[RR^{t+\tau-1}/(1 + r_t)^\tau],$$

where r_t is a real discount rate over time period t and is defined as:

(6) $$r_t = (1 + \delta_t)/(1 + \rho_t) - 1.$$

To sum up, the basic logic of the NPV method requires estimating the stream of resource rents that are expected to be earned in the future, followed by discounting these estimated future resource rents back to the beginning of the present accounting period, and then adding up the discounted values. This provides an estimate of the value of the asset based on the information set acquired and formed at that point in time.

Thus, as a prerequisite and also a point of departure, the resource rent has to be estimated before measuring the value of an asset, such as the asset value of petroleum resources.

[9] More discussions can be found in subsection 4.2.

3. Estimating the resource rent

3.1. Definition and sources of resource rent

Resource rent is defined in 2008 SNA as '*the income receivable by the owner of a natural resource (the lessor or landlord) for putting the natural resource at the disposal of another institutional unit (a lessee or tenant) for use of the natural resource in production*.' (United Nations *et al*., 2009).

According to SEEA-CF, resource rent '*is best considered to be the surplus value accruing to the extractor or user of an asset calculated after all costs and normal returns have been taken into account*.' (United Nations *et al*., 2014).

Arguably, the SEEA-CF definition pays a slightly more attention to how to measure resource rent in practice by suggesting calculating it as a surplus value. But both the SNA and SEEA-CF definitions share the same notion that resource rent is a kind of return specific to the natural resource that is used in production, alluding to that it can be regarded as capital services, defined as the contribution to production in a modern framework for capital measurement (e.g., Schreyer, 2009).

In essence, just like capital services that are provided by fixed capital, resource rent consists of two parts: one part representing depletion which can be regarded as cost (similar to consumption of fixed capital for fixed capital), and the other part representing income generated by or net return to the natural resource (similar to net return to fixed capital). However, 2008 SNA treats depletion as 'other change in the volume of assets' rather than production cost (United Nations *et al*., 2009). On the contrary, SEEA-CF explicitly considers depletion as production cost (United Nations *et al*., 2014).

Regarding the sources from which resource rent is generated and accrues to the extractor or user of an asset, there exist a number of different theories. If roughly divided, the origins of sources include the following categories as presented in a recent SNA update Guidance Note (Smith, 2022):

- Differential rents (also called Ricardian rents) that accrue to the more productive factors of production in homogenous input markets. A classic example is differential rents generated from land with different qualities.
- Scarcity rents (or absolute rents) arise when demand exceeds supply in the long run. An example is entrepreneurial rent.
- Marshallian short-run/quasi rents that arise in the short-run when demand exceeds supply at a fixed point in time and are dissipated as the prospect of rent capture encourages more entrants to the market.

It is worth noting that different sources of resource rent are not mutually exclusive in reality and consequently the estimates of resource rent that underpin the NPV method as described in subsection 2.2 should not be regarded as emerging from any one particular source of resource rent.

3.2. Methods available for resource rent estimation

There are in general three methods available for resource rent estimation in practice. The first is the appropriation method which estimates resource rent using the actual payments made by extractors to owners of natural resources. In many countries, governments are the legal owners of natural resources on behalf of the country at large. As legal owners, the governments could in theory collect the entire resource rent derived from extraction of the resources that they own, through various mechanisms such as fees, taxes, and royalties paid by the extractors.

Although the required data by applying this method are often readily available from government accounts, the fees, taxes, and royalties actually collected may tend to understate the total resource rent generated, as the relevant rates may be set with other priorities in mind by the governments, for example, for encouraging investment and employment in extraction industries.

As the second method for resource rent estimation, the access price method is based on the observation that access to resources may be controlled through the purchase of licenses and quotas. When these resource access rights are freely traded, the rights themselves (in whatever forms, such as written contracts and/or issued licenses) become a type of asset. Thus, it is possible to estimate the value of the relevant resource rents from the transacted market prices of the rights/asset.[10]

While theoretically appealing, however, in practice, governments may give access rights directly to extractors for free or do so at a price that is less than the true market value. Moreover, trading of the rights may be restricted or prohibited in some countries. Under such circumstances, there may be no directly observable market valuation.

The third available method for estimating resource rent in practice is the residual value method which may be the most commonly applied method. By this method, resource rent is estimated by deducting user costs of produced assets from gross operating surplus (GOS) after adjustment for any specific taxes and subsidies, by means of national accounts statistics for the production unit extracting natural resources.

In principle, the above-mentioned three methods should generate the same estimates of resource rent, given the equivalence of the economic reasoning behind. For example, the economic logic behind the access price method parallels that for the residual value method, because it is expected that, in a free market, the value of the total rights should be equivalent to the future returns from the asset in concern (after deducting all costs, including user costs of produced assets).

However, in reality the application of either the appropriation method or the access price method is more heavily influenced by institutional arrangements in a specific country. For these reasons, it is suggested by the international statistical standard that estimates of resource rent based on the residual value method by applying national accounts statistics should be compiled wherever appropriate (see United Nations *et al*., 2014).

In Norway, it is found that a significant part of the total resource rent generated through petroleum extraction activities stays with the extraction industry, although a substantially larger part is collected by the government through various mechanisms, such as taxes, royalties, and even direct engagement (see Liu, 2023). This observation is not in favor of the application of the appropriation method for estimating the resource rent in Norway.

Further, despite a few pieces of information existent about license transaction,[11] there is no organized market for trading the licenses/contracts in Norway for exploring, extracting petroleum resources on the Norwegian continental shelf. In principle, such information, if coming regularly and in large scale, may be exploited for resource rent estimation, at least for the purpose of cross-checking the estimated results with those resulted from other methods.

However, such a regular market is not yet established, and the currently available pieces of information are not mature enough to be employed for resource rent estimation for our purpose. Therefore, the access price method is not recommended either, at least for the time being.

[10] In some cases, where the access rights allow a very long or even indefinite access to the resource, the market value of the access rights could provide a direct estimate of the total value of the resource in concern.
[11] For example, see OKEA kjøper seg inn i Equinor-lisens (energiwatch.no)

3.3. The residual value method

The residual value method can be implemented by following the procedure as listed in Table 3.1 which is recommended by the SEEA-CF (United Nations *et al*., 2014). As shown in Table 3.1 which is a direct copy of Table 5.5 in the SEEA-CF, almost all items used for deriving the resource rent can be directly drawn from national accounts datasets.

Table 3.1 Deriving resource rent from the SNA measures by following the residual value method

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)

Ideally, resource rent should be calculated separately for each individual type of petroleum resources. In the Norwegian resource classification system, the petroleum resources on the Norwegian continental shelf are classified into four different types: crude oil, natural gas, natural gas liquids (NGL), and condensate. In Liu and Midttun (2024a), it is demonstrated that physical asset accounts according to the SEEA-CF standard can be compiled separately for each of the four types of petroleum resources on the Norwegian continental shelf.

However, it is hard, if not impossible, to estimate resource rent separately for each specific type of petroleum resources in practice. Because at the oilfield level which is the lowest level for reporting statistics about petroleum extraction activities on the Norwegian continental shelf, although information on the production of each type of petroleum products (i.e., oil, gas, NGL, and condensate) are available, the partitioning of production inputs by each type of petroleum products, such as the required intermediate consumption, cost of labor and produced capital, is not straightforward. For instance, for many oilfields on the Norwegian continental shelf, it is almost impossible to separate costs related to oil extraction from those related to gas extraction.

Therefore, in this paper, the resource rent from petroleum extraction activities on the Norwegian continental shelf is calculated as a whole for total petroleum resources, rather than separately for each individual type of them.

Using the residual value method to estimate the resource rent generated by the Norwegian petroleum extraction activity, there are two general approaches: the 'Aggregate' approach considers the entire petroleum extraction industry as one production unit and calculates the resource rent accordingly; the 'Bottom-up' approach estimates the resource rent first from the oilfield level and then sums up the oilfields' results to arrive at an aggregate one.

Recently, the 'Bottom-up' approach 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 2008 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 or the oilfield level.

Based on a simple model, Liu and Midttun (2024b) demonstrates that under some modest and practical assumptions, the estimates of the asset value of petroleum resources by following either the 'Aggregate' or the 'Bottom-up' approach 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 availability and quality of the data to be used by each approach.

Based on a thorough investigation on the data availability and quality at the oilfields level, Liu and Midttun (2024b) further illustrates 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. As a result, the resource rent generated by the Norwegian petroleum extraction activities will be calculated by following the 'Aggregate' approach in this paper.

Applying the standard procedure as described in Table 3.1 to estimate the resource rent, there are still several issues that merit some further discussions.

Specific taxes (subsidies)

As shown in Table 3.1, after the gross operating surplus on the basis of the SNA framework (hereafter SNA GOS) is derived,[12] specific taxes should be added to, while specific subsidies should be deducted from the derived SNA GOS, in order to arrive at a new 'gross operating surplus' term for the purpose of calculating resource rent.

In 2008 SNA and ESA 2010, taxes (subsidies) related to production can be classified into two broad categories: 'taxes (subsidies) on products', and 'other taxes (subsidies) on production' (United Nations *et al*., 2009; Eurostat, 2013). Note that the output from extraction industry as shown in Table 3.1 is valued at basic prices, which excludes taxes while includes subsidies on products. In addition, other taxes less other subsidies on production have also been deducted as part of operating costs because they are treated in 2008 SNA and ESA 2010 as a charge on value added and can be considered as some kind of remuneration to the general government.

Therefore, if some of taxes (subsidies) related to production, no matter they are product taxes (subsidies) or other taxes (subsidies) on production, are believed to be 'specific' in the sense that they apply solely to the natural resource extraction activities and are not generally applicable across the economy (United Nations *et al*., 2014), these 'specific' taxes should be regarded as part of the resource rent that is generated due to the extraction activity, and thus should be added back to the SNA GOS and thus included in the estimated resource rent; while the 'specific' subsidies are considered to be part of the cost that is involved with the extraction activity, and therefore, should be deducted from the SNA GOS accordingly.

[12] Strictly speaking, the SNA GOS calculated as such also includes gross mixed income (the surplus earned by unincorporated enterprises) and should be adjusted for net taxes and subsidies on production (United Nations et al., 2014). But these details do not affect the logic of the explanation provided, and they are not relevant for the Norwegian case.

Although conceptually clear, to figure out which types of taxes (subsides) are specific, and which are not in practice will necessarily involve subjective judgement to some extent. For example, in Norway, some people may think that levied 'Environmental taxes' and 'Area fees' to oil and gas extraction are 'specific' to the petroleum extraction activities, while others regard them not as 'specific' since they may also be imposed on other industries.

Consequently, the resource rent in this paper will be separately calculated and tested for two cases: one considers both 'Environmental taxes' and 'Area fees' as 'Specific taxes' on extraction, and the other treats neither 'Environmental taxes' nor 'Area fees' as 'Specific taxes' on extraction'.[13]

For the petroleum extraction activities, 'Environmental taxes' include mainly the carbon tax and the NOx tax, and 'Area fees' are intended to ensure that awarded acreage for economic activities is explored efficiently by the petroleum extraction activities.

In Norway, there is another special tax imposed on the petroleum extraction industry which is levied on the profit of the industry.[14] This kind of special income tax should be considered as redistribution of resource rent and thus pure transfer between the government and the petroleum extraction industry. Therefore, this redistribution should be registered in the secondary distribution of income account and has no impact on the total amount of resource rent which is generated from extracting petroleum resources and is supposed to be derived from the production and generation of income account in the national accounts.

Rate of return to produced capital

As shown in Table 3.1, starting from a new 'gross operating surplus' term, user costs of produced capital that are used in the petroleum extraction industry have to be deducted, which include two components: consumption of capital or capital depreciation, and return to produced capital.

Usually, capital stock and depreciation can be derived by applying the well-known Perpetual Inventory Model (PIM) and are relatively easy to obtain. Thus, the issue of calculating return to produced capital boils down to an issue of how to choose the rate of return to produced capital.

In the growth accounting literature, there are two broad approaches to estimating the rate of return to produced capital: one is the *ex-post* approach, and the other is the *ex-ante* one.[15] One frequently applied *ex-post* measure in empirical research is to estimate an internal rate of return for an industry by imposing the condition that the estimated value of capital services provided by produced capital exactly correspond to the SNA GOS in that industry.

If this endogenous *ex-post* approach is applied to the petroleum extraction industry, it will inevitably give rise to an upward-biased estimate of the rate of return that is to be used for estimating the resource rent by following the residual value method, because the SNA GOS includes not only the capital services by produced capital, but also those generated by the natural resources, while the latter has not been accounted in the total stock of produced capital. Therefore, using the endogenous *ex-post* approach to estimating a rate of return specific to the petroleum extraction industry is not supposed to be recommended.

On the other hand, following the *ex-ante* approach, the rate of return can be exogenously chosen, for example, as an average of different interest rates that prevail on financial markets that bear a link to the opportunity costs of investing in non-financial assets, such as interest rates on

[13] By following the same approach, Liu (2023) found that the difference between the estimated resource rents from the two cases (with and without 'Environmental taxes' and 'Area fees') is small.
[14] The special income taxes are calculated by using a tax rate of 71.8 %, which leads to a combined marginal tax rate of 78 % on the oil and gas companies' net profit.
[15] Both approaches have strengths and weaknesses, on which more discussions can be found in e.g., Schreyer (2009).

government bonds, corporate bonds, and corporate debt of varying maturity. Schreyer (2008) has shown that exogenous rates can coexist with occurrences of non-observed assets, imperfect competition and non-constant returns to scale that are not allowed by the endogenous *ex-post* approach.

One difficulty related to the *ex-ante* approach is what exactly to be chosen as the exogenous rate of return. Work at the OECD where exogenous real rates have been used for capital services measurement at the total economy level showed that in the 18 countries examined, long-run averages of real interest rates oscillated around values between 3% and 5% per year, depending on the country (Schreyer, 2009).

According to Norwegian Ministry of Finance (2012b), for public projects with normal risk and a horizon of under 40 years, a real rate of return of 4% is recommended, which consists of a risk-free part of 2.5% and a risk-adjustment of 1.5%. However, for other projects with high systematic risk, the use of a higher rate of return is required. For instance, in a report to the Norwegian Parliament by the Ministry of Petroleum and Energy as regards the development and operation of new oil fields, 7% is recommended to be used as the real rate of return (Norwegian Ministry of Petroleum and Energy, 2018).

As for empirical research in Norway, a fixed 4% is used as the real rate of return to produced assets by the Norwegian Technical Calculation Committee for Wage Settlements.[16] In several other studies, both 4% and 7% are utilised as rates of return to produced assets for calculating resource rent generated from petroleum extraction activities in Norway (e.g., Greaker and Lindholt, 2022; Liu, 2023).

There is another way to obtain a rate of return to be used for resource rent estimation. In Liu (2016, 2023), a normal rate of return is defined in each year as the net operating surplus divided by the net stock of produced assets in Mainland Norway[17] (excluding government owned assets[18]) for that year. The rationale is that in equilibrium, investors should expect the same return from offshore petroleum extraction as that from the other (market) sector in the mainland of Norway. This normal rate of return is then applied for calculating the resource rent for the petroleum extraction industry.

This method is essentially an opportunity cost approach and is consistent with the resource rent definition as given by SEEA-CF, i.e., 'the amount of resource rent is always derived relative to the returns earned by other firms on average over time, i.e., normal returns' (United Nations *et al*., 2014). In addition, this method can be regarded as a hybrid method because it combines the *ex-post* and the *ex-ante* approaches and is similar to that in Oulton (2007) where first an *ex-post*, endogenous rate is computed and then the *ex-ante* rate is chosen as the trend of the *ex-post* rate of return. Thus, this hybrid method has the advantage in that it avoids the problem of selecting arbitrarily an exogenous rate of return while preserving the *ex-ante* nature of the calculation.

Moreover, despite possible biases,[19] this hybrid method is practically feasible and relatively easy to be implemented because the needed data for net operating surplus and net stock of produced assets for all but the petroleum extraction industries can be directly drawn from annual national accounts datasets in Norway.

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[16] *Det tekniske beregningsutvalget for inntektsoppgjørene (TBU)* in *Norwegian*.
[17] Mainland Norway is an economic concept that is formed by excluding the offshore industries related to petroleum extraction activities from the whole Norwegian economy.
[18] According to SNA 2008, the capital return to government owned assets is set equal to zero.
[19] More discussions on the possible sources of bias can be found in Liu (2016).

In this paper, three options of rate of return will be used for resource rent calculation: the first two are 4% and 7%, exogenously given as *ex-ante* annual real rate of return, and the third one is the estimated nominal rate of return by using the hybrid method just described.

Note that both 4% and 7% refer to the rates of return in real terms, and thus they have to be adjusted by a general rate of inflation to arrive at those in nominal terms, so that these nominal rates of return can be applied for estimating the annual resource rent together with other variables in nominal terms. The selected general inflation rate is presented in the second column of Table 3.2 and will be discussed later in subsection 3.3.

On the other hand, the estimated rate of return by using the hybrid method refers to a nominal rate of return and can be directly used for resource rent estimation. Therefore, in the rest of the paper, unless stated otherwise, the estimated rate of return refers to nominal rate of return, while 4% and 7% refer to real ones.

Labour compensation

As shown in Table 3.1, labour compensation should be deducted as labour costs in order to estimate resource rent by following the residual value method. There exist different views about whether labour compensation in the petroleum extraction industry as recorded in the national accounts should be directly applied here without any further adjustment.

In recognition of the abnormally high wages/salaries paid in the petroleum extraction industry, some may think that it is the high operating surplus (including resource rents) in the industry that gives rise to more room for the negotiation of wages/salaries between the labour union and the employers in the petroleum industry than in other industries.

Therefore, the so-called normal labour costs for the petroleum extraction industry, different from those registered in the national accounts, should be calculated as the multiplication of an average wages/salaries per hour for Mainland Norway and the total actual working hours in the offshore petroleum extraction industry (e.g., Greaker *et al*., 2005; Greaker and Lindholt, 2022). This idea is similar to what is applied by the hybrid method for deriving the rate of return to produced capital.

However, others may argue that as the value of labour contributing to the production process, labour input costs reflect a kind of 'capital services' generated by human capital embodied in those employees working in the petroleum extraction industry. Because specific knowledge are needed for working in this industry, it might be more reasonable to consider the high wages/salaries as simply to reflect the market value of the special knowledge embodied.

This view is in accordance with the way human capital is calculated by means of the lifetime income approach (see e.g. Liu, 2014). Moreover, it is also consistent with the observation also made by Greaker and Lindholt (2022) that lower wages/salaries in e.g. agriculture, forestry, fishing industries are primarily due to lower educational level found in these industries.

Another aspect is the high degree of risk associated with the work on oil platform at the Norwegian Continental Shelf, especially at the beginning of the extraction period. Extreme weather conditions combined with many manual operations, especially in the early decades, caused a number of accidents as well as serious health problems. Thus, higher than average salaries in the petroleum industry in Norway might be seen as necessary for employees to be willing to take the increased risk.

As a result, the labour compensation as actually registered in the national accounts, rather than the calculated normal labour costs in the petroleum extraction industry will be used for calculating the resource rent in this paper, by following the procedures in Table 3.1.

Other unaccounted assets

By using the residual value method to estimate the resource rent as formulated by Table 3.1, it is worth keeping in mind that the calculated residual value will bring together all measurement flaws, either in terms of measurement errors for each of the components used for the calculation, or in terms of missing assets that are not yet accounted in today's accounting system, such as organizational asset, marketing asset, other natural resources, social capital etc.

These unaccounted assets are currently ignored in the formulation as presented in Table 3.1 and returns to these unaccounted assets will thus end up with the calculated resource rent by following the residual value method. In the future, once the currently unaccounted assets are included in the asset boundary of the updated accounting system, the residual value method can be improved.[20]

3.4. Estimated historical resource rent (1970-2020)

Nominal resource rent (in current prices)

By means of the residual value method, historical resource rents generated from the Norwegian petroleum extraction industry over the period 1970-2020 are estimated. Except for the return to produced assets, almost all the items needed for estimation as listed in Table 3.1 can be obtained from the NNA database and Government Finance Statistics (GFS) at Statistics Norway.[21]

As mentioned, three options of the rate of return are chosen: 4% and 7% as real rates of return, and one nominal rate of return that is estimated by the hybrid method just described in subsection 3.2. The estimated results reflect the differences due to the choice of rate of return. In addition, the estimates also distinguish between those with specific taxes included and those without.

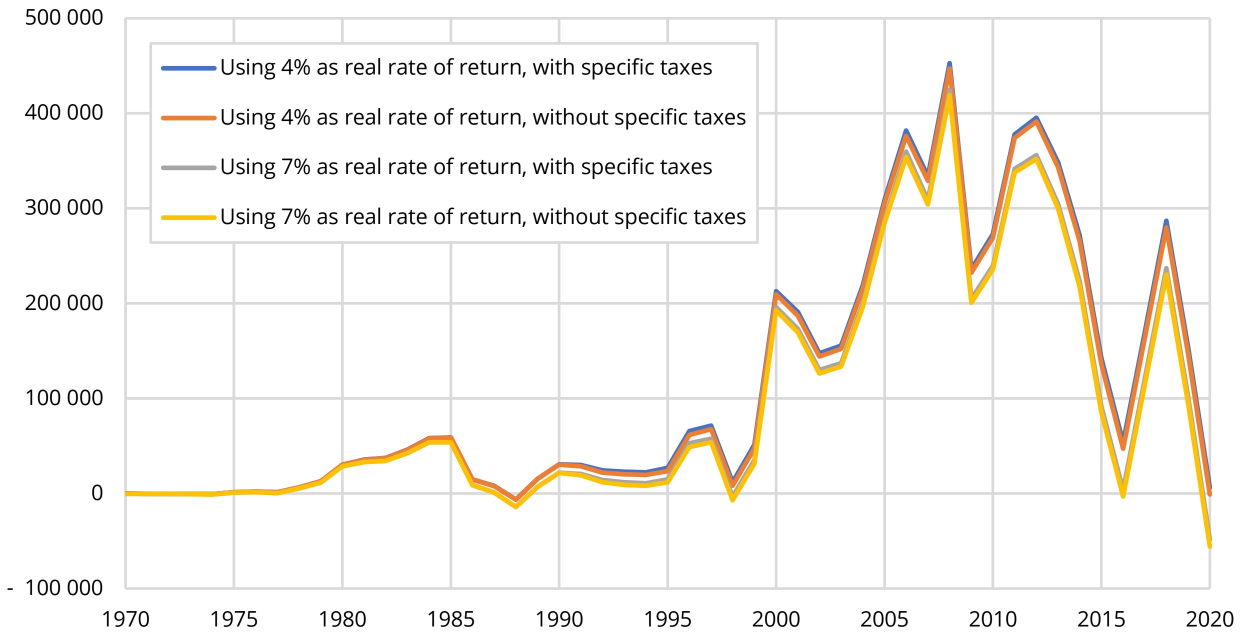
Since the fixed two rates of return, 4% and 7% are in real terms, they have to be adjusted by a general rate of inflation in order to obtain the corresponding nominal rates of return. In this paper, the annual price change of a general consumption is chosen as the general rate of inflation in the Norwegian economy. The general consumption is defined as the sum of all types of final consumption in the economy, which includes not only household final consumption expenditure, but also final consumption expenditure of general government (both central and local government), as well as of non-profit institutions serving households (NPISHs).

In cases where the annual price change of general consumption is not available, other price indexes may be applied instead, such as the consumer price index (CPI). However, though CPI is usually available in most countries, it is worth mentioning that CPI reflects the price change of the household final consumption expenditure only.

The data about the annual price change of the general consumption over the period 1970-2021 are directly drawn from the StatBank at Statistics Norway,[22] and are presented in the second column of Table 3.2. The fixed 4% and 7% rates of return are *ex-ante* measures, and thus implicitly having smoothed the relevant time series of observed rates because it is implausible that economic actors fully anticipate every movement of market rates. Therefore, to arrive at the corresponding nominal rate of return, the adjustment should be undertaken by means of an averaged general price change of inflation in the economy.

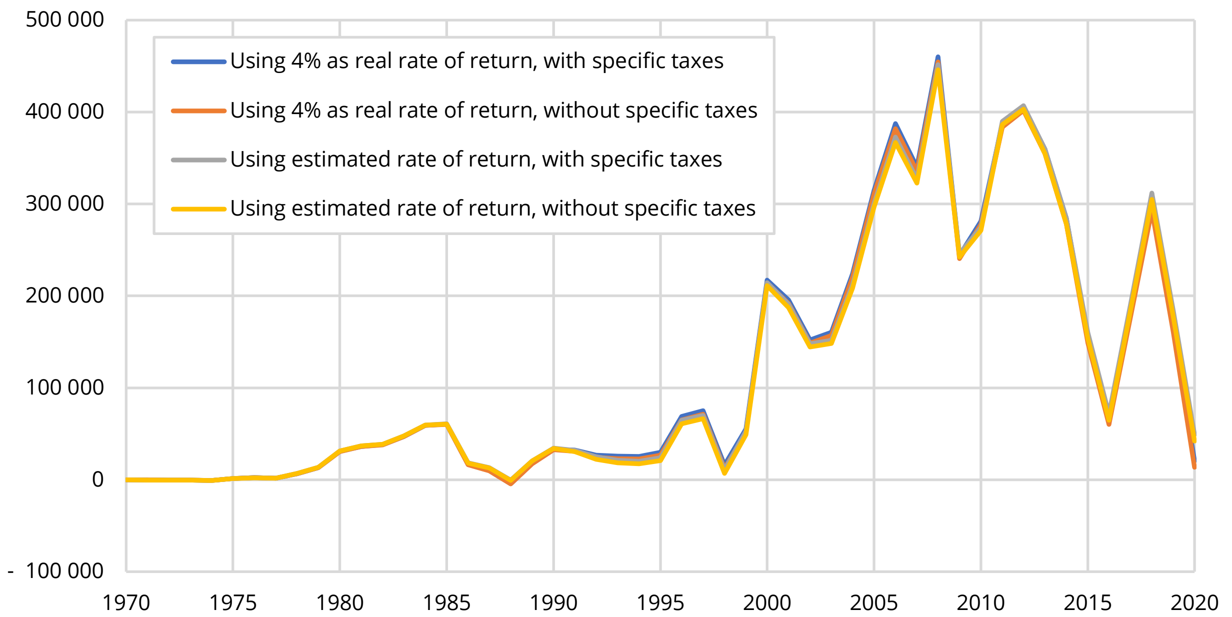
[20] Marketing asset is now suggested to be included in the asset boundary of the updated SNA (SNA 2008 Update Project Team, 2023).
[21] The data used for resource rent estimation in this paper are downloaded in January 2024 from the StatBank, an online data bank at Statistics Norway (https://www.ssb.no/en/statbank).
[22] See Table 09185 at: https://www.ssb.no/en/statbank/table/09185

Figure 3.1 Estimated nominal resource rent (current prices, NOK million), using 4% vs. 7% as real rate of return



Source: Authors' own calculation based on data from Statistics Norway.

Figure 3.2 Estimated nominal resource rent (current prices, NOK million), using 4% as real rate of return vs. estimated rate of return



Source: Authors' own calculation based on data from Statistics Norway.

Based on the data as shown in the second column of Table 3.2, a geometric average over the period 1970-2020 is calculated as 4.7% per annum.[23] Thus, if 4% is chosen as a real rate of return, its

[23] The corresponding arithmetic average is also around 4.7% per annum.

corresponding nominal rate of return is calculated as (1+4%) (1+4.7%) -1, which is around 8.9%; if 7% is chosen, the corresponding nominal rate of return is as (1+7%) (1+4.7%) -1, which is about 12%.

Figure 3.1 displays the estimated nominal resource rents, i.e., in current prices (NOK million), over the period 1970-2020, by using 4% vs. 7% respectively as real rate of return to produced capital. As shown, there are some differences of estimates between 4% and 7% as real rate of return, with the latter being less than the former. The differences appear to be larger over some subperiods than over others, for example, after 2008, the differences are more visible.

However, for each chosen real rate of return, either 4% or 7%, the differences of estimates between those including specific taxes and those excluding them are almost no discernible. As a matter of fact, if the resource rent is calculated with specific taxes included, the average share of the specific taxes in the total resource rent over the whole period 1970-2020 is about 5.5% for both chosen real rates of return.

This is also true for Figure 3.2 in which the estimated nominal resource rents in current prices (NOK million) over the period 1970-2020 are displayed by using 4% as real rate of return and by the estimated rate of return respectively. If the estimated rate of return is taken, the average share of the specific taxes in the total resource rent over the whole period 1970-2020 is about 2.9%.

In addition, a similar pattern to Figure 3.1 is also observed in Figure 3.2 in terms of the peaks and troughs appeared, but the differences of estimates between the two chosen rates of return are rather small. Note that the average estimated rate of return over the observed period 1970-2020 is around 8.4%,[24] which is very close to 8.9%, the corresponding nominal rate of return if the fixed 4% is taken as a real rate of return.

All the estimates in numbers behind Figures 3.1 and 3.2 are reported in Table A1 in Appendix A. As shown in Table A1, the estimated resource rents for the early period 1970-1974 are all negative, regardless of the choice of rate of return to produced capital, and with or without specific taxes being included. In fact, the SNA GOS of the petroleum extraction industry is negative during this period, due to none or very low production while high investment incurred at the early development stage of petroleum extraction activities debuted on the Norwegian continental shelf.

As for other years, negative resource rents appear in 1988 for all three chosen rates of return and no matter whether specific taxes are included. With or without specific taxes, the estimated resource rents are negative in 1998 and 2020 when the real rate of return is chosen as 7%. When specific taxes are not included, the estimated resource rent is negative in 2020 if the real rate of return is chosen as 4%, and in 2016 if the real rate of return is chosen as 7%.

Given that the differences of the estimated resource rents between those with specific taxes included and those without are small, we decide that from now on, unless stated otherwise, the resource rents that will be estimated and reported in the rest of the paper all include specific taxes.

Real resource rent (in constant 2021 prices)

In Table 3.2, the estimated real resource rent is reported in constant 2021 prices (in NOK million) over the period 1970-2020, by using 4%, 7% as real rates of return, and the estimated one as nominal rate of return to produced capital. The real resource rent is obtained by the corresponding nominal resource rent as reported in Table A1 in Appendix A deflated by a constructed price index.

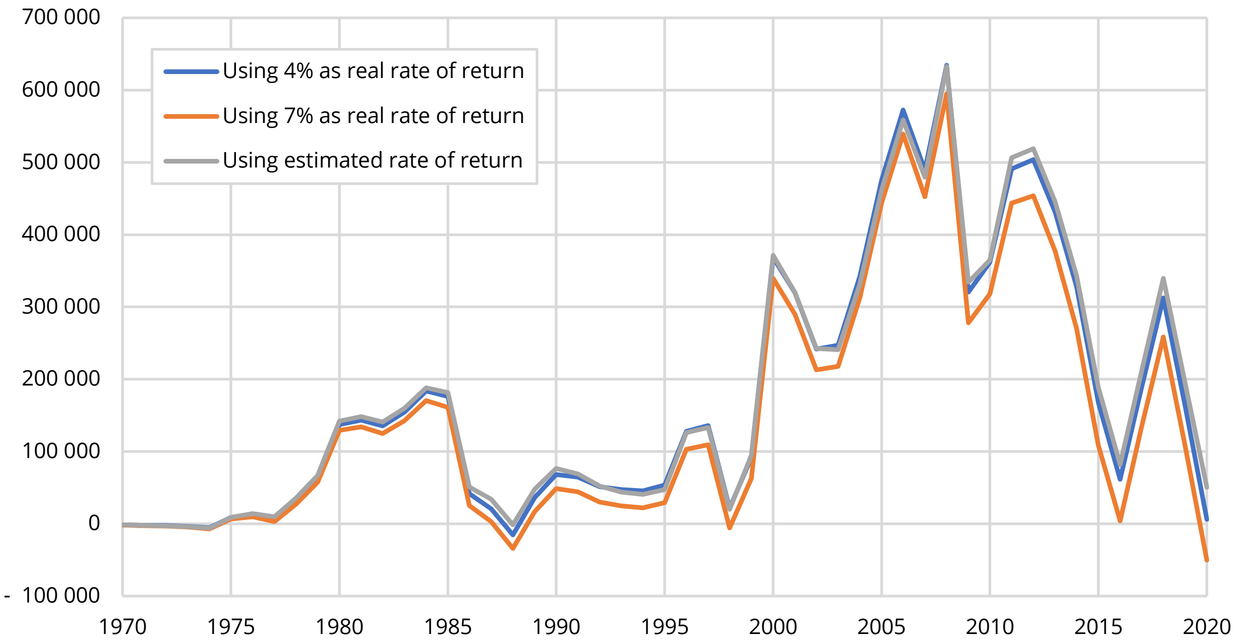
[24] Interestingly, 8.5% is sometimes chosen as the rate of return to human capital in the wealth accounting literature (see e.g., Arrow *et al*., 2010; UN University –International Human Dimensions Programme (UNU-IHDP) and the UN Environment Programme (UNEP), 2012, 2014).

Table 3.2 Constructed price index and estimated real resource rent (in 2021 prices, NOK million), 1970-2020

			Real resource rent (NOK million)		
Year	Annual price change (%)	Constructed price index (2021 =1)	Using 4% as real rate of return	Using 7% as real rate of return	Using estimated rate of return
1970	..	0.098	-1 367	-1 640	-1 444
1971	7.3	0.105	-2 176	-2 622	-2 255
1972	7.2	0.112	-2 428	-3 160	-2 548
1973	7.9	0.121	-3 680	-4 636	-3 971
1974	10.6	0.134	-5 532	-7 234	-6 036
1975	11.5	0.149	8 907	6 422	8 760
1976	9.4	0.164	13 341	9 786	13 952
1977	8.9	0.178	8 491	3 179	9 923
1978	8.2	0.193	33 279	27 630	36 015
1979	4.7	0.202	64 131	57 549	67 050
1980	9.5	0.221	137 414	129 477	141 916
1981	12.2	0.248	143 489	134 170	148 341
1982	11.1	0.275	135 694	124 871	140 748
1983	8.2	0.298	154 425	142 713	159 842
1984	6.2	0.316	183 771	170 523	188 195
1985	5.9	0.335	176 351	161 092	181 606
1986	7.2	0.359	41 732	25 183	50 887
1987	8.7	0.390	20 891	2 974	33 864
1988	5.7	0.413	-15 394	-34 099	-1 233
1989	4.6	0.432	36 081	16 795	47 706
1990	4.0	0.449	68 230	48 781	76 789
1991	3.5	0.465	64 426	44 413	68 975
1992	2.0	0.474	51 261	29 943	52 446
1993	2.2	0.484	47 337	24 559	43 594
1994	1.2	0.490	45 593	21 984	40 802
1995	2.7	0.503	53 372	29 326	47 348
1996	1.9	0.513	127 947	102 991	126 140
1997	2.6	0.526	135 750	109 532	133 118
1998	3.4	0.544	21 892	-5 997	19 737
1999	2.5	0.558	91 777	62 724	94 943
2000	3.5	0.577	368 581	339 438	371 596
2001	3.4	0.597	319 758	290 041	320 165
2002	2.2	0.610	241 869	212 869	242 575
2003	3.2	0.630	247 144	217 967	240 969
2004	1.7	0.640	342 553	313 052	331 743
2005	1.5	0.650	475 772	444 269	462 014
2006	2.6	0.667	572 541	539 185	558 861
2007	2.3	0.682	489 204	452 733	479 750
2008	4.6	0.714	634 537	595 059	632 850
2009	3.1	0.736	320 782	278 116	334 278
2010	2.4	0.753	361 935	317 798	364 689
2011	2.2	0.770	490 919	443 684	506 641
2012	1.9	0.785	504 003	453 635	518 889
2013	2.9	0.807	431 310	377 252	445 317
2014	2.6	0.828	328 089	270 176	342 987
2015	2.5	0.849	167 826	108 457	188 413
2016	2.7	0.872	61 448	3 829	81 818
2017	2.3	0.892	190 590	136 028	213 099
2018	2.9	0.918	312 681	258 462	339 759
2019	2.8	0.944	163 152	108 053	194 905
2020	2.8	0.970	6 335	-50 267	50 454
2021	3.1	1.000	..	..	..

Source: Authors' own calculation based on data from Statistics Norway.

Figure 3.3 Estimated real resource rent (in constant 2021 prices, NOK million), using 4% and 7% as real rates of return, and estimated rate of return



Source: Authors' own calculation based on data from Statistics Norway.

The constructed price index is derived by means of the annual percentage price change of the general consumption as just defined above, under the consideration that resource rent or more precisely, the depletion-adjusted resource rent or net income is expected to ultimately meet the needs for general consumption, i.e., not only for final consumption of household, but also for those of general government and NPISHs.

In order to estimate the real resource rent in constant 2021 prices, the price index is constructed by setting the price of 2021 equal to 1 and the price for other years is adjusted accordingly by using the annual price change. The constructed price index with the price of 2021 equal to 1 is reported in the third column of Table 3.2.

Note that in the last row of Table 3.2, the estimated resource rent for 2021 is not available, because at the beginning of 2021 or the end of 2020, actual resource rent generated in 2021 is not supposed to be known.

The estimated real resource rent in constant 2021 prices (NOK million) over the period 1970-2020 by using 4% and 7% as real rates of return, and the estimated one as nominal rate of return is also displayed in Figure 3.3. Generally speaking, using the estimated one as nominal rate of return gives the largest estimated real resource rent, followed by those using 4% and 7% as rate of return, respectively.

But overall, the differences of the estimated real resource rent are not very large among the three chosen rates of return to produced capital. As shown, while the differences between the two real rates of return, i.e., 4% and 7% are visible, especially over some period of years, the estimated real resource rents by using the estimated one as nominal, and 4% as real rate of return are close to each other.

4. Measuring the asset value

In this section, the NPV method as described in subsection 2.2 will be implemented at the beginning of 2021for measuring the asset value of petroleum resources on the Norwegian continental shelf for the period 1970-2021. Formally, in order to apply equation (1) or equation (5) to measuring the asset value, some projections are needed such as the future production, price, and cost profiles over the remaining years of extraction. These profiles are predicted with the information formed at the beginning of 2021 or the end of 2020.

Around the end of each year, based on experts' assessment, the Norwegian Offshore Directorate (formerly the Norwegian Petroleum Directorate) will make prediction of future production profile of petroleum extraction activities on the Norwegian continental shelf from then until around 2050/2060.[25] For the purpose of preparing annual national budget plan, the Norwegian Ministry of Finance extends the future predicted production profile until around 2085/2090 when all the petroleum resources on the Norwegian continental shelf are believed to be exhausted. In addition, the Ministry also makes forecasts about the future price profiles of petroleum products (e.g., Norwegian Ministry of Finance, 2022).

Note that the future production profile predicted by both the Norwegian Offshore Directorate and the Norwegian Ministry of Finance on an annual basis has the quantity information separately for the four types of petroleum resources found on the Norwegian continental shelf: crude oil, natural gas, natural gas liquids (NGL), and condensate. By using a common metric, i.e., Sm^3 o. e. [26], the sum of the four types of petroleum resources in quantity can be derived.

However, the predicted future production profile does not distinguish the petroleum resources between different classes, i.e., Class A (Commercially recoverable resources), Class B (Potentially commercially recoverable resources), and Class C (Non-commercial and other known deposits), as suggested by the SEEA -CF. Moreover, it includes 'Potential deposits' that are not suggested to be included in the SEEA-CF classifications (United Nations *et al*., 2014). In other words, separate prediction of future production profile for each and every class or category is currently not available.

As a result, the total petroleum resources, both discovered and undiscovered, i.e., the sum of both Classes A, B and C, and the "Potential deposits' are considered in this paper. Then the stock concept of petroleum resources at the beginning of an accounting year in this paper is equivalent to the concept of 'Remaining resources' as applied in the Norwegian petroleum resources classification system, which are equal to the 'Total resources' minus 'Produced' that is the accumulated historical production, all entries being recorded in the annual petroleum resource accounts published by the Norwegian Offshore Directorate at its website [27] (see Liu and Midttun, 2024a).

In previous Norwegian studies (e.g., Brunvoll, *et al*., 2012; Liu, 2016), the predicted profiles including production and price are applied for estimating the future resource rents. In Liu (2016), a prediction based on historical cost trend is in addition applied for the estimation of future resource rents.

Indeed, there exist enormous difficulties associated with the prediction of the expected production, price, and cost profiles related to petroleum extraction activities. For instance, the future price of petroleum products is very hard to predict due to the volatility of oil and gas prices that are exogenously determined in the international market.

[25] For more information, please refer to https://www.sodir.no/aktuelt/publikasjoner/rapporter/.
[26] Sm^3 o. e. is an abbreviation of standard cubic metres of oil equivalents.
[27] https://www.npd.no/en/facts/resource-accounts-and-analysis/

In recognition of these difficulties, a relatively simple but still robust method will be applied in this paper, which is based on historical information of the unit resource rent, with the assumption that the pattern/trend as reflected in the history may still hold into the future. Although history may not always repeat itself, it is not unreasonable to make prediction about the future by using the historic as well as the current information that are available at the beginning of an accounting period for which the asst value is to be estimated.

4.1. Nominal unit resource rent (in current prices)

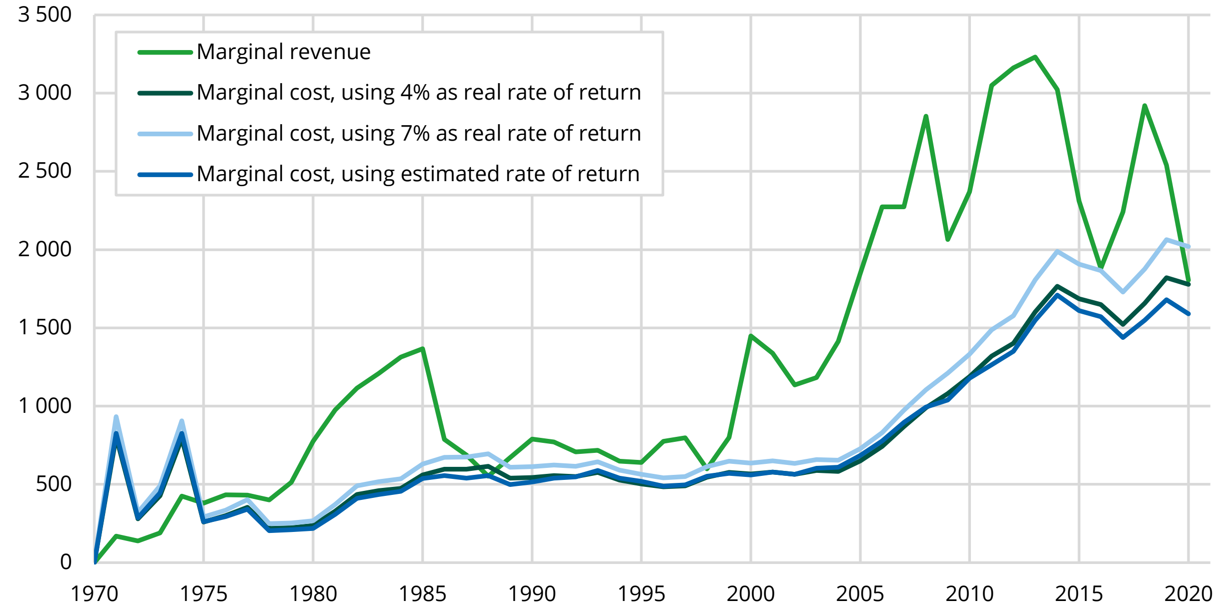
Marginal revenue and marginal cost

In this paper, the marginal revenue (MR) for the petroleum extraction industry is defined as the sum of annual total output (in basic prices) and specific taxes divided by annual production in quantity, and the marginal cost (MC) is defined as the annual total production cost divided by annual production in quantity. The total production cost includes not only the operating costs but also the user costs of produced capital, the sum of capital depreciation and the return to produced capital (see Table 3.1).

The nominal unt resource rent (in current prices) in each year is therefore defined in this paper simply as the difference between the MR and the MC in that year, which is consistent with the residual value method for resource rent estimation as described in Section 3.

The data of the quantity of production (in Sm^3 o. e. million), and of the value of production in basic prices, specific taxes, and total cost (in NOK million) over the period 1970-2020 are presented in Table A2 in Appendix A.

Figure 4.1 Estimated marginal revenue and marginal cost (in current prices, NOK per Sm^3 o. e.), 1970-2020



Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

Figure 4.1 displays the calculated MR, and the MC by three chosen rates of return over the period 1970-2020. The corresponding estimates are reported in Table A3 in Appendix A. As shown, the MC has been increasing gradually over the observed period, except for the early period 1971-1974 [28], when the MC was larger than the corresponding MR, leading to negative resource rents for these years.

[28] The MR and MC are not calculated for 1970 because the production in quantity in 1970 is zero.

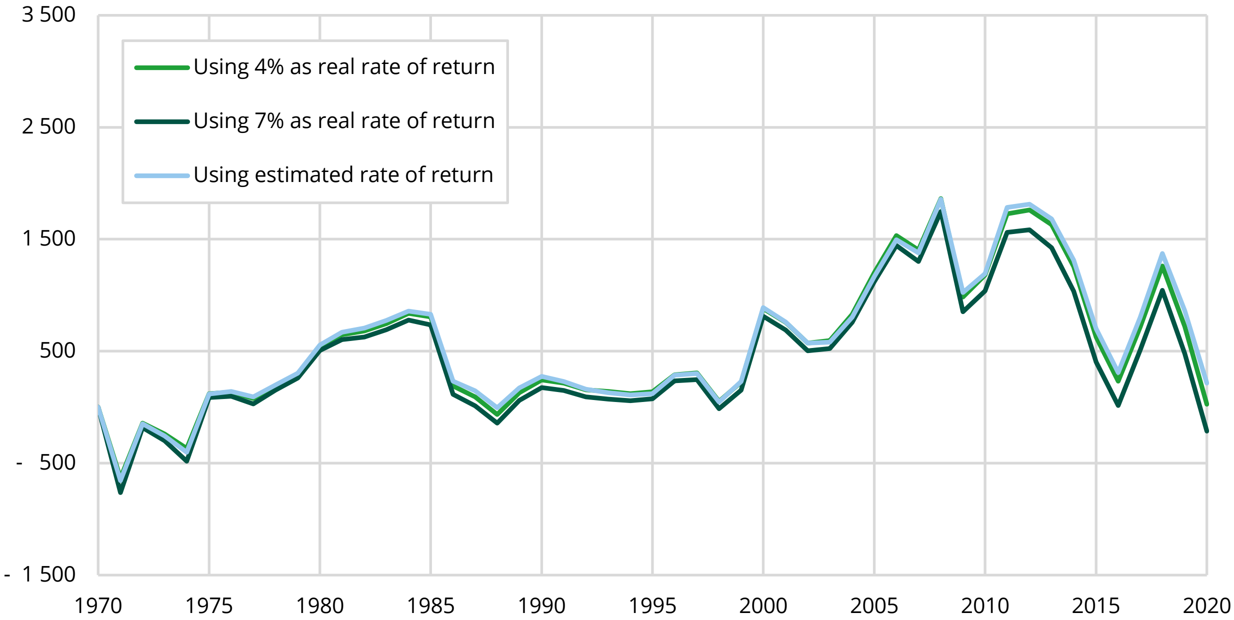
Table 4.1 Estimated nominal and real unit resource rent (NOK per Sm³ o. e.), 1970-2020

	Unit resource rent, nominal (in current prices)			Unit resource rent, real (in 2021 prices)		
Year	Using 4% as real rate of return	Using 7% as real rate of return	Using estimated rate of return	Using 4% as real rate of return	Using 7% as real rate of return	Using estimated rate of return
1970	..	..	..	..	..	..
1971	-633	-763	-656	-6 046	-7 283	-6 263
1972	-141	-184	-148	-1 258	-1 638	-1 320
1973	-239	-301	-257	-1 968	-2 479	-2 123
1974	-369	-482	-403	-2 752	-3 599	-3 003
1975	121	87	119	810	584	796
1976	134	99	141	822	603	860
1977	78	29	91	439	164	513
1978	182	151	197	943	783	1 021
1979	289	259	302	1 433	1 286	1 498
1980	539	508	556	2 439	2 298	2 518
1981	647	605	669	2 610	2 440	2 698
1982	680	626	706	2 471	2 274	2 563
1983	748	691	774	2 509	2 319	2 597
1984	838	777	858	2 647	2 456	2 711
1985	806	736	830	2 405	2 197	2 477
1986	190	115	232	529	319	646
1987	91	13	148	233	33	378
1988	-65	-143	-5	-157	-347	-13
1989	130	60	172	301	140	398
1990	244	174	274	543	388	611
1991	215	148	231	463	319	496
1992	156	91	160	330	193	337
1993	140	73	129	290	150	267
1994	122	59	109	248	120	222
1995	136	75	121	271	149	240
1996	290	234	286	565	455	558
1997	306	247	300	581	469	570
1998	52	-14	47	96	-26	86
1999	223	152	230	399	273	413
2000	882	812	889	1 528	1 407	1 540
2001	759	688	760	1 271	1 153	1 272
2002	571	503	573	936	824	939
2003	595	524	580	944	833	921
2004	830	759	804	1 297	1 185	1 256
2005	1 201	1 121	1 166	1 847	1 725	1 794
2006	1 532	1 443	1 496	2 298	2 164	2 243
2007	1 405	1 300	1 378	2 059	1 906	2 020
2008	1 863	1 747	1 858	2 611	2 449	2 605
2009	983	852	1 025	1 336	1 159	1 393
2010	1 182	1 038	1 191	1 569	1 378	1 581
2011	1 729	1 562	1 784	2 245	2 029	2 317
2012	1 760	1 584	1 812	2 244	2 019	2 310
2013	1 629	1 425	1 682	2 018	1 765	2 084
2014	1 256	1 034	1 313	1 516	1 249	1 585
2015	625	404	702	737	476	827
2016	232	14	309	266	17	355
2017	718	512	803	805	575	900
2018	1 262	1 044	1 372	1 375	1 137	1 495
2019	720	477	860	763	505	911
2020	27	-215	216	28	-221	222
Mean (1971-2020)	553	455	576	838	615	866
Mean (1975-2020)	632	532	658	1 172	995	1 218

Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

On the contrary, as also shown in Figure 4.1, the MR over the same observed years (1970-2020) demonstrates a more volatile pattern. More significantly, the swings as appeared in the MR curve resemble to the largest extent those appeared in the estimated total resource rents as shown in both Figure 3.1 and Figure 3.2. Clearly, the volatility of the estimated annual total nominal resource rent comes mainly from the MR, which is primarily driven by the price volatility of petroleum products in the international markets.

Figure 4.2 Estimated nominal unit resource rent (in current prices, NOK per Sm³ o. e.), 1970-2020



Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

Note that the choice of rate of return only affects the calculated MC but not the MR, nonetheless, it will impact the estimated nominal unit resource rent (in current prices) that are shown in the first three columns in Table 4.1 and displayed in Figure 4.2.

As shown in Figure 4.2, the estimated nominal unit resource rent (in current prices) displays a similar pattern, in terms of peaks and troughs, to that revealed by the MR in Figure 4.1 (and the total nominal resource rent in Figure 3.1 and Figure 3.2 as well), although the swing amplitude is much smaller. In addition, the nominal unit resource rent also shows a gradually increasing trend.

4.2. Real unit resource rent (in constant 2021 prices)

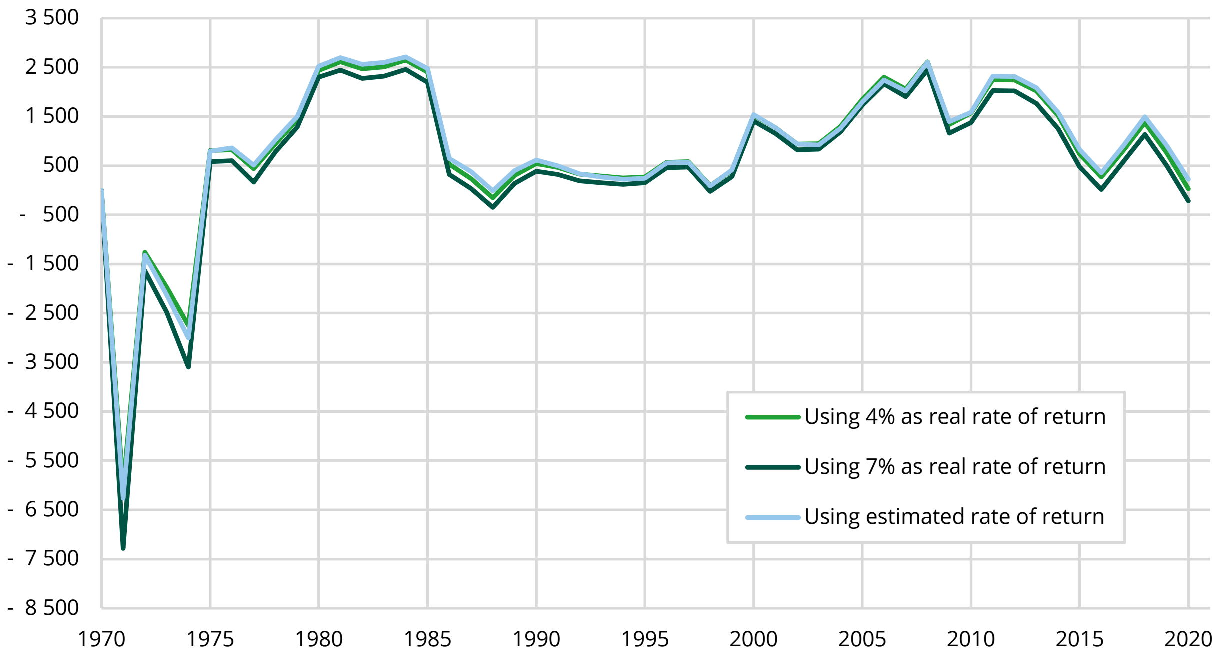
Real unit resource rent (in constant 2021 prices) is calculated as nominal unit resource rent divided by the constructed price index (with 2021 = 1) as shown in the third column of Table 3.2. The estimated results are presented in the last three columns in Table 4.1 and displayed in Figure 4.3.

As displayed, except for the early period 1971-1974, the estimated real unit resource rent (in constant 2021 prices) is still volatile but arguably, it seems to swing around a long-term average. The revealed pattern of historical real unit resource rent can be used for forecasting the future expected unit resource rent and thus estimating the asset value by following the NPV method.

The estimated average unit resource rent, both in nominal (or in current prices) and in real (or in constant 2021 prices), and by the three chosen rates of return, is presented in the last two rows in Table 4.1, one for the average over the period 1971-2020, and the other for that over the period 1975-2020.

Because it is impractical to use the unit resource rent in last year to make prediction for the future, in cases where the unit resource rent in last year is estimated as negative, as it is accidentally the case in 2020 in Norway as shown in Table 4.1 when 7% is chosen as real rate of return, countries may use different methods to smooth out the volatility of historical unit resource rent. For example, Australian Bureau of Statistics (2013) applies a 5-year lagged average, while Statistics Netherlands uses a 3-year average (Veldhuizen, *et al*., 2009).

Figure 4.3 Estimated real unit resource rent (in constant 2021 prices, NOK per Sm^3 o. e.), 1970-2020



Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

The main purpose of taking an average over a long time period is to smooth out the volatility of resource rent so that a relatively stable estimate can be reached, which is considered to be a reasonably good prediction for future resource rent in a long-term perspective rather than in a short-term one.

In this paper, the real unit resource rent (in constant 2021 prices) averaged over the period 1975-2020 (see the last row in Table 4.1) will be used for the estimation of the asset value of petroleum resources on the Norwegian continental shelf at the beginning of 2021 or the end of 2020.

4.3. The choice of discount rate

As shown by equations (1) and (5), applying the NPV method to measuring the asset value requires the choice of a suitable discount rate, either in nominal or in real terms, another essential component meriting some discussions.

As shortly stated in subsection 2.2, a discount rate is needed to adjust the value of a stream of future flows such as incomes or costs so that the value of future flows can be compared with the value of flows in the current period, owing basically to that the value of money in the future is not the same as, and usually worth less than, the value of money at present.

Clearly, time preference plays an important role in shaping to what extent the current period should be preferred to the future, and thus in determining the value of the discount rate. In general, a higher discount rate should be applied if the current period is preferred much to the future, while a lower discount rate implies that the current period is relatively indifferent from the future. Because future is often uncertain, risk preference will also play a deterministic factor to gauge the value of the discount rate.

For the choice of discount rate, there is another issue to be considered. Speaking of both time and risk preferences, one may raise a question as regards whose preferences should be taken into account, are they individual consumers or firms, or a social planner on behalf of the society as a whole. If it is the former, then individual discount rates should be applied, while if it is the latter, social discount rates should be used instead.

Individual discount rates focus on information concerning the return needed by the individual consumer or firm to justify investment in the current period with the aim of receiving income or other benefits in the future, by taking account the degree of risk associated with the investment. There is a clear link between the choice of such discount rates and the concept of market prices for assets.

On the other hand, from the perspective of a social planner, social discount rates take into consideration not only efficiency, but also equity between and within current and future generations because discount rate is frequently applied to projects that may involve inequality concern and last over long periods of time.

The application of discount rate in this paper is to measure the asst value of petroleum resources by following the NPV method that is regarded as aligning with the market price valuation principle as both applied by 2008 SNA and suggested by SEEA-CF. Therefore, it is the individual discount rate that will be applied even if the borderline between the individual and social discount rate is not always clearcut and a number of thorny issues are still unresolved in this field.

In this paper, three alternatives, i.e., 1%, 4%, and 7% are chosen as annual real discount rate for the estimation of the asset value of petroleum resources on the Norwegian continental shelf. Note that a real discount rate is one that has been adjusted to remove the impact of general inflation, whereas a nominal discount rate has not undergone any such adjustment.

A number of countries (e.g., Australia, Canada, the Netherlands) use 4% as a fixed real discount rate for the compilation of natural resources by following the NPV method (Pionnier and Yamaguchi, 2018). In Norway, the 4% real discount rate was also applied in Norwegian Ministry of Finance (2000), Greaker *et al*. (2005), and Liu (2016) for national wealth accounting. Besides, the 4% real discount rate is consistent with that the annual expected long-term real rate of return to the Government Pension Fund Global (GPFG) was set as 4% by the Norwegian Ministry of Finance (2012a).[29]

In addition, 7% was once applied as the expected annual real discount rate in Brekke *et al*. (1989) and Liu (2016). The real discount rate of 1% was once chosen in Liu (2016), but the main purpose is for making sensitivity analysis with respect to the choice of discount rate. For the same purpose, 1% as real discount rate will also be applied in this paper.

4.4. Estimated asset value of Norwegian petroleum resources (1970-2021)

This subsection will illustrate formally how to implement the estimation by following the NPV method in detail. The implementation is assumed to be done at the beginning of 2021 with future prediction available about annual petroleum production in quantity X^t (t = 2021, 2022, ..., 2090), which is made by the Norwegian Ministry of Finance.

[29] The annual expected long-term real rate of return to the GPFG was 4% until February 2017, after when it is reduced to 3%.

For simplicity, the real discount rate r_t is assumed to be a constant r for the whole period 1970-2090 covered by this paper, meaning that starting from the beginning of any year during the period 1970-2021, of which the asset value will be estimated, the future real discount rate is *r*. In other words, the real discount factor after the first year is $(1+r)^{-1}$, and that after the second year is $(1+r)^{-2}$, and so on.

Estimated asset value in constant 2021 prices

Estimating the asset value for 2021

For estimating the asset value of petroleum resources for 2021, or more accurately from an accounting perspective, at the beginning of 2021 (or the end of 2020), the average real unit resource rent in constant 2021 prices over the period 1975-2020, UR_R^*, which is calculated in subsection 4.2, will be treated as the expected real unit resource rent in 2021, $UR_R^* = UR_R^{2021}$.

The future annual nominal unit resource rent and nominal discount rate are assumed to evolve in line with a constant general rate of inflation, ρ, which is assumed to be constant over all the future years until 2090, starting from the beginning of 2021.

Then, using equations (1) – (5) yields:

(7) $$V^{2021B} = NR^{2021}/(1+\delta_{2021}) + NR^{2022}/(1+\delta_{2022})^2 + \cdots + NR^{2090}/(1+\delta_{2090})^{70}$$

$$= (UR_N^{2021}X^{2021})/(1+\delta_{2021}) + (UR_N^{2022}X^{2022})/(1+\delta_{2022})^2 + \cdots$$

$$+(UR_N^{2090}X^{2090})/(1+\delta_{2090})^{70}$$

$$= [(UR_R^{2021}X^{2021})(1+\rho)]/[(1+r)(1+\rho)] + [UR_R^{2021}(1+\rho)^2X^{2022}]/[(1+r)(1+\rho)]^2 + \cdots$$

$$+[UR_R^{2021}(1+\rho)^{70}X^{2090}]/[(1+r)(1+\rho)]^{70}$$

$$= (UR_R^{2021}X^{2021})/(1+r) + (UR_R^{2021}X^{2022})/(1+r)^2 + \cdots + (UR_R^{2021}X^{2090})/(1+r)^{70}.$$

Then the future resource rent in constant 2021 prices in each future year is calculated as the product of the expected real unit resource rent and the predicted future production in quantity in that year. These future resource rents will be discounted back to the beginning of 2021 (or the end of 2020), and by summing up these flows, an estimate of the asset value of petroleum resources at the beginning of 2021 (or the end of 2020) can be obtained.

Estimating the asset value for 1970-2020

For estimating the asset value of petroleum resources for the years during the period 1970-2020, the procedure is implemented backward, i.e., with the estimated asset value at the beginning of 2021, V^{2021B} ready, the asset value at the beginning of 2020, V^{2020B} is calculated first, and followed by that of 2019, V^{2019B}, and then that of 2018, V^{2018B}, and so on:

(8) $$V^{2020B} = RR^{2020}/(1+r) + V^{2021B}/(1+r),$$

$$V^{2019B} = RR^{2019}/(1+r) + V^{2020B}/(1+r),$$

$$V^{1970B} = RR^{1970}/(1+r) + V^{1971B}/(1+r).$$

At the beginning of 2021 (or the end of 2020), all the resource rents during the period 1970-2020 are *ex-post* (or actually realized, as denoted by RR^{1970}, RR^{1971}, ..., RR^{2020} in equation (8)) rather than *ex-*

ante (or expected) and these resource rents in constant 2021 prices are presented in Table 3.2 in subsection 3.3.

Ideally, if every piece of information needed for measuring the asset value at the beginning of each year for the period 1970-2020 is readily available, the implementation procedure for estimating the asset value for 2021 as just described above in equation (7) can be applied in exactly the same way for estimating the asset value for the period 1970-2020, i.e., by exclusively using *ex-ante* rather than combining with *ex-post* resource rents. Then equation (8) is not needed. However, it is very challenging, if not impossible, to apply only equation (7) for implementing back-casting in practice.

Here is an example. At the beginning of a year during the period 1970-2020, say, 2015, even if a predicted future production profile made at the beginning of 2015 by the Norwegian Ministry of Finance indeed can be found from the archive, the relevant national accounts data at that time (such as production, intermediate consumption, labour and capital costs etc. for the petroleum extraction industry) is not easy to find, given the fact that National Accounts had gone through various small and/or large revisions over years, unless a perfect archive is well maintained with all vintages of national accounts data being stored.

Given data limitation, equation (8) has to be employed. In other words, to estimate the asset value at the beginning of 2015, starting from then, all the future resource rents are discounted back to the beginning of 2015. These future resource rents consist of two parts: one part is the *ex-post* or realized resource rents (in constant 2021 prices) as shown in Table 3.2 for the period from the beginning of 2015 to the end of 2020, the other part is the *ex-ante* or expected resource rents from the beginning of 2021 and onwards, with expectation being made at the beginning of 2021, because the compilation is *de facto* carried out at the beginning of 2021 with all information available up to that point of time.

To sum up, combining equations (7) and (8) for constructing time-series estimates seems to be a more practical procedure for a country starting to establish such accounts for the first time at the beginning of a specific year, such as 2021 as presented in this paper.

Up to now, since all the annual resource rents applied in equations (7) and (8) are in constant 2021 prices, the estimated asset value of Norwegian petroleum resources are also in constant 2021 prices.

Equations (7) and (8) can be generalized as the following:

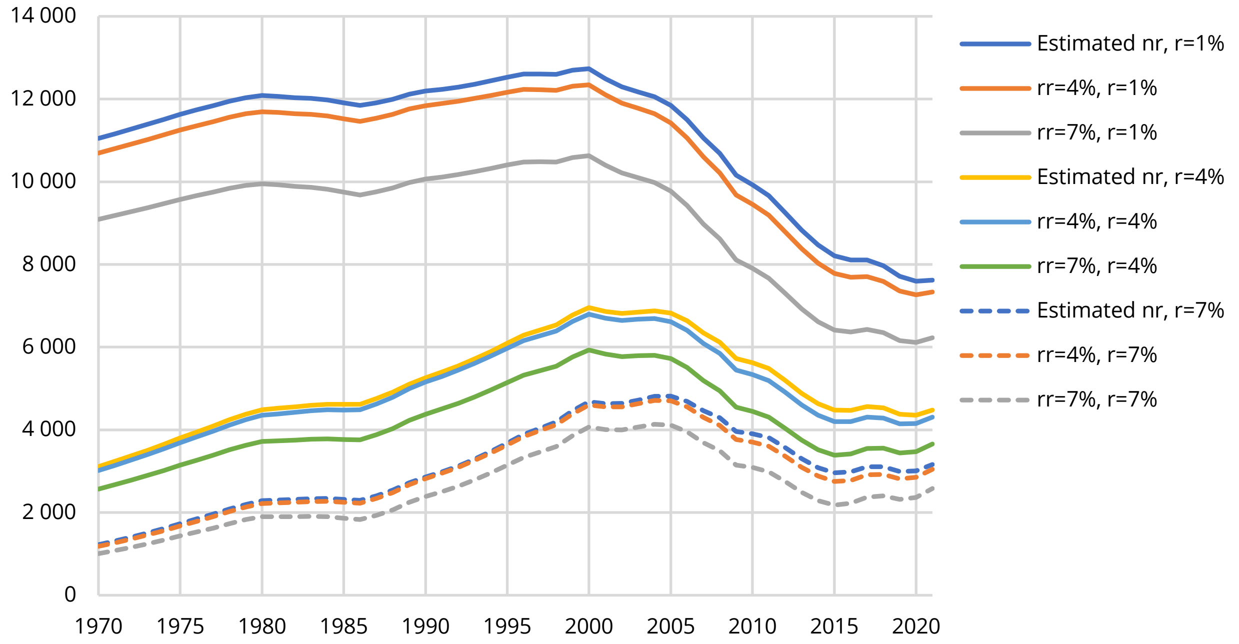
$$(9)\qquad V^{t-1B} = RR^{t-1}/(1+r) + \left\{\sum_{\tau=1}^{T^{tB}} [RR^{t+\tau-1}/(1+r)^{\tau}]\right\}/(1+r)$$

$$= (RR^{t-1} + V^{tB})/(1+r).$$

As shown, to arrive at an estimated asset value at the beginning of *t-1*, not only the resource rent generated in year *t-1*, but also all the future resource rents, generated starting from the beginning of year *t*, should be discounted back to the beginning of year *t-1*, while the latter has just been discounted back to the beginning of year *t* to give rise to the estimated asset value at the beginning of year *t*. Therefore, the estimated asset value at the beginning of year *t* should be further discounted one more year back for the purpose of estimating the asset value at the beginning of year *t-1*.

The estimated asset value of Norwegian petroleum resources in constant 2021 prices over the period 1970-2021 are reported in Table A4 in Appendix A. Figure 4.4 displays the estimated results cross-classified by the rate of return to produced capital and the discount rate. Note that 'Estimated nr' refers to the estimated annual nominal rate of return to produced capital by using the hybrid method applied in this paper, and 'rr' to the annual real rate of return as the *ex-ante* measures. Finally, 'r' refers to the annual real discount rate.

Figure 4.4 Estimated asset value of Norwegian petroleum resources (in constant 2021 prices, NOK billion), 1970-2021



Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: 'Estimated nr' stands for 'estimated annual nominal rate of return' and 'rr' for 'annual real rate of return' to produced capital in petroleum extraction industry; 'r' stands for 'annual real discount rate'.

Recall that following the NPV method as described in subsection 2.2, the estimated asset value at the beginning of year *t* in equation (5), V^{tB} is monotonically decreasing with respect to the discount rate r_t , because the following inequality holds:

(10) $$\partial V^{tB}/\partial r_t = -\sum_{\tau=1}^{T^{tB}}[\tau RR^{t+\tau-1}/(1+r_t)^{\tau+1}] < 0.$$

As a result, for each chosen rate of return to produced capital, the estimated asset value is larger if the chosen discount rate is smaller. In addition, following the residual value method to estimating the resource rent as described in subsection 3.2, it is also intuitively clear that for each chosen discount rate, the larger the chosen rate of return to produced capital, the lower the estimated resource rent, and so the estimated asset value.

Therefore, as shown in Figure 4.4, the highest curve has the rate of return equal to the estimated one and the discount rate equal to 1%, while the lowest curve has the real rate of return being 7% and the discount rate being 7% as well, and all the other curves with different combination of the rate of return and the discount rate lie somewhere in between as shown in Figure 4.4.

There are some other interesting observations. It seems that for each chosen rate of return to produced capital, when the discount rate increases from 1% to 4% and further to 7% with marginal change being constant 3% by each step, though the estimated asset value decreases as expected, the marginal effect itself is decreasing. In addition, when the discount rate increases by 3% by each step from 1% until 7%, the differences of the estimated asset values due to the different chosen rate of return are decreasing as well.

By reorganizing, equation (9) becomes:

(11) $$V^{tB} - V^{t-1B} = -RR^{t-1} + rV^{t-1B}.$$

Equation (11) illustrates that the change of the estimated asset value between (the beginning of) two consecutive years, *t-1* and *t*, consists of two items: the first item is the resource rent generated in year *t-1* with a negative sign; and the second item may be interpreted as the return to capital, which is positive. Whether the change of the estimated asset value is positive or negative, and thus whether the curve as shown in Figure 4.4 is increasing or decreasing between two consecutive years, depends on the sign of the sum of the two items.

Alternatively, a rough reasoning can be made by intuition. By following the NPV method to measure the asset value, when moving one year forward, one year of resource rent disappears in the calculation, meanwhile, all the future resource rents that should be discounted will be discounted with one year less, if the latter effect, which is positive in general [30], is larger than the former effect, which is negative, the estimated asset value will increase, otherwise, it will decrease, if compared with that before moving.

Estimated asset value in current prices

Using the constructed price index as reported in the third column of Table 3.2, which sets the price of 2021 equal to 1, the asset value of Norwegian petroleum resources in current prices can be calculated by multiplying the constructed price index with the above estimated asset value in constant 2021 prices.

However, recall that the price index constructed in this paper is based on the annual price change of general consumption, and is used previously for deriving the resource rent in constant prices from that in current prices. Both general consumption and resource rent are flows, implying that the constructed price index refers to the price level during an accounting period, which is usually approximated by the price level at the middle of an accounting period, if the accounting convention is complied with.

Following the accounting convention, stocks are supposed to be measured either at the beginning or at the end of an accounting period. Thus, strictly speaking, a price index more conceptually suitable for measuring the asset value in constant prices should be compiled instead, which differs from those as shown in the third column of Table 3.2.

One possible approximation for compiling such an asset price index at the beginning of an accounting period *t* is to take the average of prices of resource rent in two consecutive periods *t-1* and *t* (see e.g., Schreyer, 2009; Liu, 2024):

(12) $$P_V^{tB} = (P_R^{t-1} + P_R^{t})/2, \quad t = 1971, 1972, \dots, 2021,$$

where P_V^{tB} is the compiled asset price index at the beginning of time period *t*, while P_R^{t-1} and P_R^{t} are the constructed price index of resource rent for two consecutive time periods *t-1* and *t*, respectively, as presented in the third column of Table 3.2.

Nonetheless, in this paper, the constructed price index as reported in the third column of Table 3.2 will still be used as a proxy for converting the asset value between constant prices and current prices. The main reason is that measuring the asset value of petroleum resources in this paper is

[30] Because $(1 + r) > 1$ holds and future resource rents are positive in general.

primarily meant to incorporate it into the balance sheet accounts, together with other assets in the NNA.

Table 4.2 Estimated asset value of Norwegian petroleum resources and fixed assets in total Norwegian economy (in current prices, NOK billion), 1970-2021

Year	Discount rate									Fixed assets
	Using 4% as real rate of return			Using 7% as real rate of return			Using estimated rate of return			
	1%	4%	7%	1%	4%	7%	1%	4%	7%	
1970	1 044	295	116	887	251	98	1 079	304	119	273
1971	1 131	329	133	962	280	113	1 169	339	137	300
1972	1 225	367	153	1042	312	130	1 266	378	158	333
1973	1 336	412	177	1136	351	150	1 380	425	182	373
1974	1 492	474	209	1269	404	179	1 542	489	216	452
1975	1 681	551	251	1430	470	214	1 738	568	259	525
1976	1 856	625	292	1580	534	250	1 919	645	302	610
1977	2 040	706	338	1736	603	289	2 108	728	349	710
1978	2 227	793	389	1896	677	334	2 302	817	402	781
1979	2 349	856	430	1999	732	369	2 427	883	443	847
1980	2 583	961	489	2199	821	419	2 669	990	505	967
1981	2 893	1 088	553	2459	926	471	2 990	1 121	571	1 103
1982	3 207	1 217	618	2723	1 033	523	3 314	1 254	637	1 255
1983	3 464	1 329	675	2938	1 125	569	3 579	1 369	696	1 386
1984	3 667	1 419	718	3107	1 197	601	3 789	1 461	740	1 518
1985	3 861	1 501	752	3266	1 262	624	3 989	1 547	776	1 664
1986	4 117	1 611	800	3478	1 349	658	4 254	1 659	825	1 848
1987	4 503	1 804	914	3808	1 515	755	4 651	1 856	939	2 100
1988	4 799	1 975	1 025	4064	1 664	853	4 951	2 026	1 048	2 339
1989	5 076	2 155	1 154	4309	1 825	969	5 231	2 204	1 174	2 421
1990	5 316	2 315	1 268	4518	1 966	1 071	5 473	2 363	1 285	2 455
1991	5 526	2 460	1 372	4701	2 094	1 163	5 686	2 508	1 387	2 531
1992	5 662	2 579	1 467	4821	2 200	1 249	5 825	2 627	1 481	2 572
1993	5 819	2 716	1 579	4962	2 324	1 351	5 987	2 767	1 595	2 641
1994	5 925	2 836	1 687	5060	2 434	1 451	6 098	2 891	1 705	2 726
1995	6 123	3 006	1 831	5238	2 589	1 583	6 305	3 067	1 853	2 891
1996	6 274	3 158	1 969	5375	2 728	1 711	6 465	3 226	1 996	3 041
1997	6 434	3 302	2 094	5516	2 857	1 824	6 633	3 376	2 125	3 220
1998	6 646	3 477	2 243	5701	3 013	1 959	6 854	3 558	2 279	3 411
1999	6 868	3 695	2 448	5905	3 215	2 151	7 085	3 782	2 488	3 596
2000	7 126	3 924	2 658	6137	3 424	2 346	7 351	4 016	2 701	3 830
2001	7 222	4 000	2 721	6206	3 480	2 393	7 455	4 097	2 767	4 049
2002	7 260	4 056	2 780	6229	3 522	2 440	7 500	4 159	2 830	4 149
2003	7 415	4 201	2 918	6359	3 646	2 561	7 665	4 311	2 972	4 267
2004	7 458	4 285	3 017	6392	3 716	2 647	7 719	4 406	3 080	4 576
2005	7 423	4 301	3 054	6350	3 720	2 671	7 697	4 435	3 130	4 954
2006	7 375	4 272	3 035	6284	3 673	2 636	7 669	4 424	3 128	5 413
2007	7 229	4 154	2 932	6125	3 540	2 518	7 542	4 326	3 042	6 028
2008	7 288	4 170	2 932	6147	3 527	2 495	7 626	4 364	3 063	6 575
2009	7 123	4 004	2 768	5963	3 344	2 315	7 475	4 213	2 913	6 964
2010	7 125	4 023	2 791	5958	3 352	2 327	7 479	4 235	2 940	7 271
2011	7 076	3 997	2 773	5905	3 318	2 300	7 439	4 221	2 934	7 780
2012	6 897	3 851	2 639	5730	3 169	2 159	7 259	4 075	2 802	8 246
2013	6 761	3 714	2 498	5589	3 025	2 011	7 125	3 942	2 666	8 717
2014	6 649	3 606	2 386	5479	2 915	1 896	7 015	3 838	2 558	9 276
2015	6 605	3 565	2 338	5443	2 878	1 850	6 971	3 800	2 514	9 781
2016	6 705	3 662	2 423	5551	2 979	1 938	7 067	3 894	2 599	10 171
2017	6 873	3 841	2 597	5732	3 166	2 118	7 228	4 070	2 771	10 568
2018	6 968	3 936	2 685	5832	3 264	2 207	7 317	4 160	2 856	11 132
2019	6 940	3 913	2 658	5812	3 245	2 184	7 276	4 127	2 821	11 739
2020	7 047	4 025	2 765	5929	3 365	2 297	7 366	4 224	2 914	12 356
2021	7 332	4 309	3 044	6225	3 658	2 585	7 620	4 478	3 164	13 177

Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

Given that the other assets already included in the balance sheet accounts, such as fixed assets, are currently compiled without the use of a suitable asset price index, e.g., as one compiled by equation (12), the application of the asset price index for petroleum resources should better follow the current practice in the NNA for the time being so that the internal consistency can be maintained. Certainly, once decision for changing the currently applied asset price index to a more conceptually suitable one (such as that as defined in equation (12)) is made, updating is straightforward.

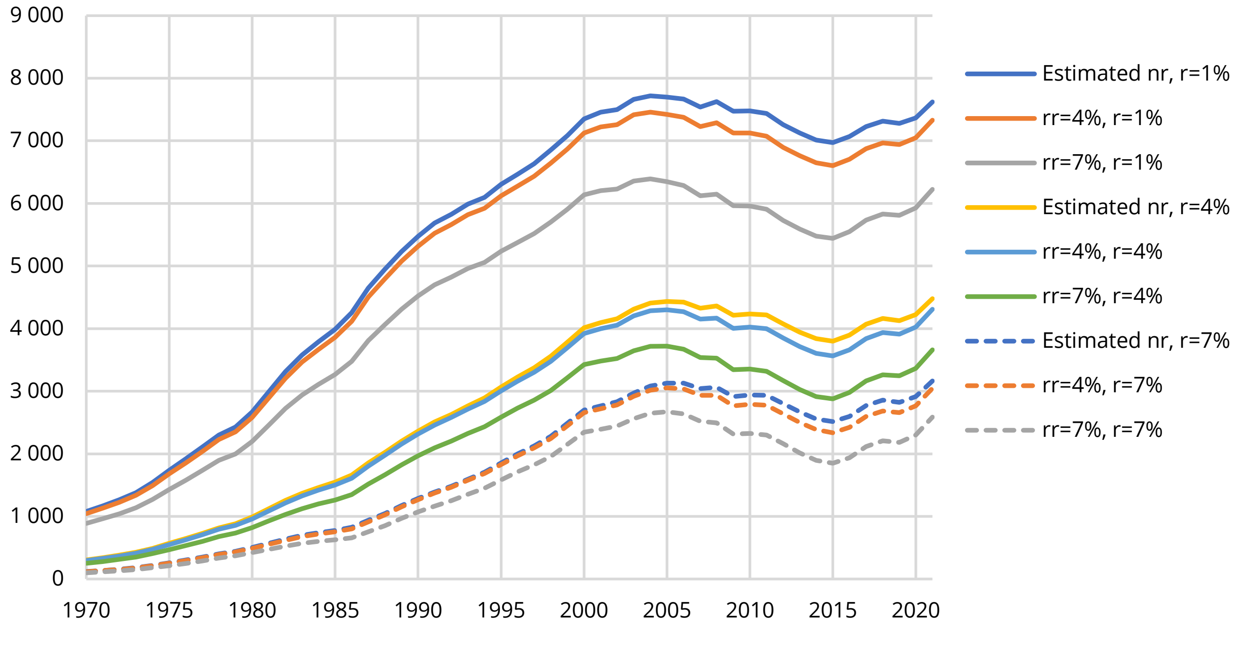
The estimated asset value of Norwegian petroleum resources in current prices over 1970-2021 are reported in Table 4.2. Figure 4.5 displays the estimated results cross-classified by the rate of return to produced capital and the discount rate.

Compared with Figure 4.4, there are some similar observations. First, it is also true that for each chosen rate of return, when the discount rate increases, the estimated asset value decreases, but the marginal effect is decreasing. Second, when the discount rate increases by 3% in each step from 1% until 7%, the differences of the estimated asset values by using the different rate of return are decreasing as well.

On the other hand, there exist also some different observations between Figure 4.4 and Figure 4.5. As shown in Figure 4.5, for each chosen rate of return, the decreasing marginal effect does not occur evenly over the years, with the marginal effect being larger in recent years than in earlier years. This is also the case for the differences due to the choice of different rate of return in that they are also larger in recent years than in earlier years as well. These observed differences are possibly due to the price effect as shown in Figure 4.5.

To sum up, Figure 4.4, which displays the estimated asset value in constant 2021 prices, by removing the price effect, gives a slightly different picture about the trend of asset value over the period 1970-2021. In general, the differences between the asset values in earlier years and those in later years become smaller, if compared with Figure 4.5, which displays the estimated asset value in current prices.

Figure 4.5 Estimated asset value of Norwegian petroleum resources (in current prices, NOK billion), 1970-2021



Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: 'Estimated nr' stands for 'estimated annual nominal rate of return' and 'rr' for 'annual real rate of return' to produced capital in petroleum extraction industry; 'r' stands for 'annual real discount rate'.

For comparison purpose, the value of fixed assets in the Norwegian economy in current prices are also presented in the last column of Table 4.2. In addition, the ratio of the asset value between petroleum resources and fixed assets in Norway is calculated over the period 1970-2021 and the results are presented in Table A5 in Appendix A.

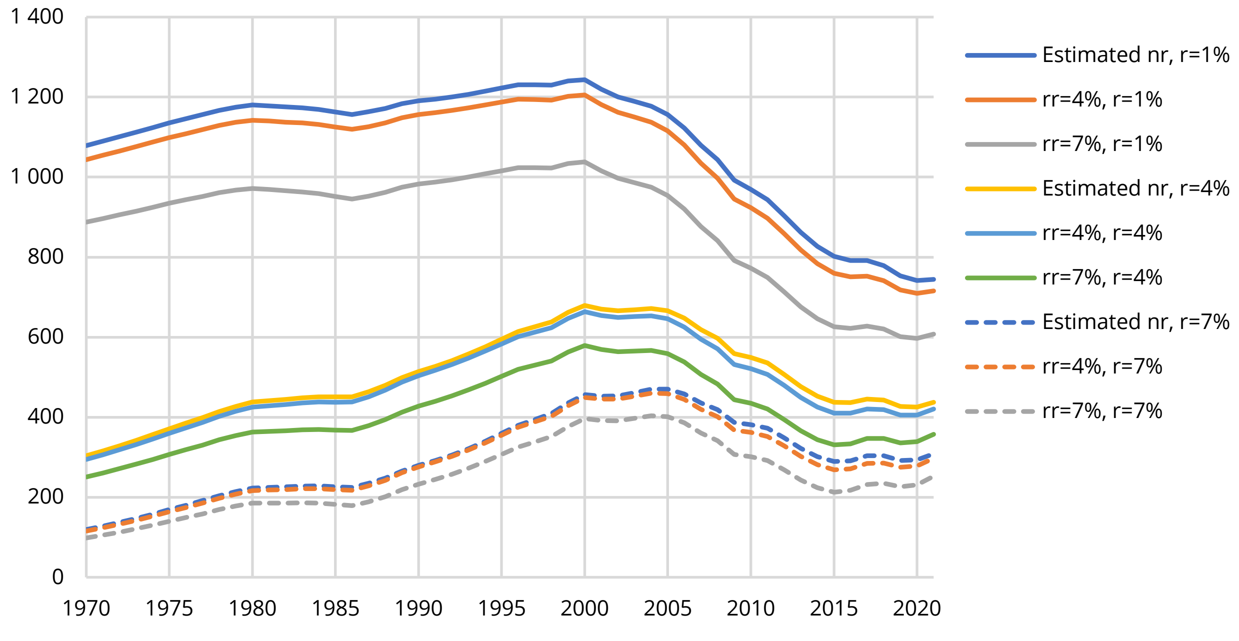
As shown in Table A5, the calculated ratios vary depending on the choice of rate of return and the discount rate, but the average (mean) value over the whole period 1970-2021 is close to the corresponding median for each combination of the rate of return and the discount rate, as shown in the last two rows of Table A5.

The average (mean) ratio is as large as 2.0, and as low as 0.4. In addition, regardless of the choice of rate of return to produced capital, the average (mean) ratio over the whole period 1970-2021 is around 1.9, 0.8, and 0.5 for the chosen discount rate equal to 1%, 4%, and 7%, respectively. Thus, on average, the estimated asset value of petroleum resources is more sensitive to the choice of discount rate than to the choice of rate of return to produced capital, which can also be observed by Figure 4.4 and Figure 4.5 as well.

Estimated asset value in constant prices of any selected year in 1970-2021

With the estimated asset value of Norwegian petroleum resources in current prices being ready, the asset value in constant prices of any selected year can be derived by dividing the estimated asset values in current prices by a suitable price index.

Figure 4.6 Estimated asset value of Norwegian petroleum resources (in constant 1970 prices, NOK billion), 1970-2021



Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: 'Estimated nr' stands for 'estimated annual nominal rate of return' and 'rr' for 'annual real rate of return' to produced capital in petroleum extraction industry; 'r' stands for 'annual real discount rate'.

To derive a suitable price index for this purpose, the constructed price index as shown in the third column of Table 3.2 will be re-calculated with the price level in the selected year being set equal to 1, certainly, with the caveats made around equation (12) being kept in mind. For example, in order to obtain an estimated asset value in constant 1970 prices, a new price index can be formed by dividing the price in each year as shown in the third column of Table 3.2 by 0.098, the price of 1970, also shown in the same column.

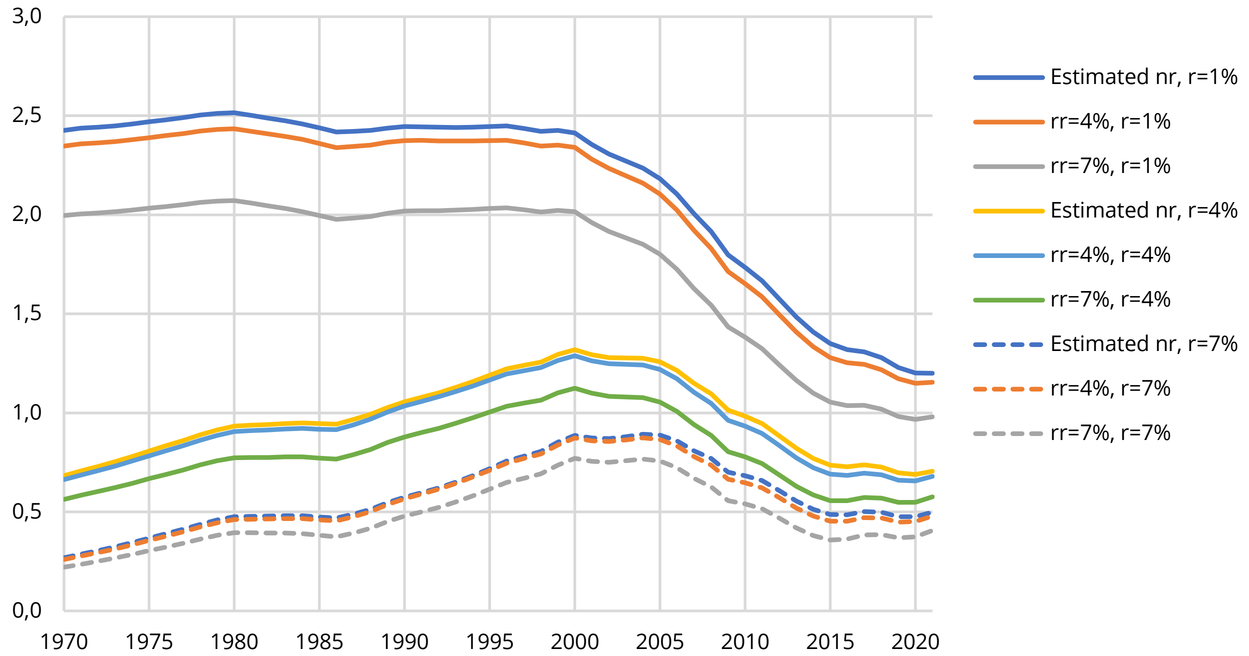
The estimated asset value of Norwegian petroleum resources in constant 1970 prices over the period 1970-2021 and are cross-classified by the rate of return to produced capital and the discount rate are presented in Table A6 in Appendix A and are also displayed in Figure 4.6.

By comparison, it appears that Figure 4.6 shows exactly the same picture as in Figure 4.4, with the only exception being that the scales and steps of Y-axis in Figure 4.6 are just about a tenth of those in Figure 4.4. In other words, the estimated asset values in constant 1970 prices are just a level shifting of those in constant 2021 prices, and the exact extent of the shift is fully determined by the price difference between the two selected years, namely, 1970 and 2021. As a matter of fact, by means of the price data for 1970 and 2021 that are directly drawn from the third column of Table 3.2, the relative price between 1970 and 2021 can be calculated as 0.098 /1 ≈ 1/10.

Estimated asset value per capita in constant 2015 prices

Currently, the times series of the asset value of fixed assets in the NNA is published in constant 2015 prices (NOK million) in the Statbank at Statistics Norway, for easy comparison and possible summation across different types of assets in constant prices in the balance sheet accounts, the asset value of petroleum resources in constant 2015 prices should also be estimated.

Figure 4.7 Estimated asset value of Norwegian petroleum resources per capita (in constant 2015 prices, NOK million/person), 1970-2021



Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: 'Estimated nr' stands for 'estimated annual nominal rate of return' and 'rr' for 'annual real rate of return' to produced capital in petroleum extraction industry; 'r' stands for 'annual real discount rate'.

Following the same procedure for generating the price index, the estimated asset value of Norwegian petroleum resources in constant 2015 prices over the period 1970-2021 and are cross-classified by the rate of return to produced capital and the discount rate are calculated and reported in Table 4.3. In the same table, the population data for the whole country (estimated on 1st January) which are directly drawn from the Statbank at Statistics Norway [31] are also reported in the last column.

[31] See Table 06913 at: https://www.ssb.no/en/statbank/table/06913/

Table 4.3 Estimated asset value of Norwegian petroleum resources (in constant 2015 prices, NOK billion) and country population (1 January, in person), 1970-2021

Year	Discount rate									Population
	Using 4% as real rate of return			Using 7% as real rate of return			Using estimated rate of return			
	1%	4%	7%	1%	4%	7%	1%	4%	7%	
1970	9 075	2 561	1 005	7 715	2 180	854	9 379	2 641	1 038	3 866 468
1971	9 167	2 665	1 076	7 794	2 268	915	9 474	2 748	1 112	3 888 305
1972	9 261	2 773	1 154	7 874	2 361	982	9 571	2 859	1 191	3 917 773
1973	9 355	2 886	1 236	7 955	2 458	1 053	9 669	2 976	1 277	3 948 235
1974	9 452	3 005	1 326	8 039	2 561	1 131	9 769	3 098	1 370	3 972 990
1975	9 551	3 130	1 424	8 125	2 669	1 216	9 872	3 227	1 471	3 997 525
1976	9 639	3 247	1 516	8 201	2 770	1 296	9 963	3 349	1 566	4 017 101
1977	9 724	3 366	1 610	8 275	2 873	1 378	10 051	3 471	1 664	4 035 202
1978	9 814	3 493	1 716	8 355	2 985	1 472	10 143	3 602	1 772	4 051 208
1979	9 884	3 605	1 808	8 415	3 081	1 552	10 214	3 715	1 866	4 066 134
1980	9 929	3 694	1 880	8 450	3 155	1 611	10 259	3 807	1 939	4 078 900
1981	9 911	3 726	1 895	8 425	3 172	1 614	10 241	3 838	1 954	4 092 340
1982	9 888	3 753	1 906	8 395	3 185	1 613	10 218	3 866	1 965	4 107 063
1983	9 872	3 788	1 924	8 373	3 206	1 620	10 200	3 901	1 983	4 122 511
1984	9 840	3 808	1 927	8 336	3 213	1 612	10 167	3 922	1 987	4 134 353
1985	9 782	3 804	1 906	8 274	3 197	1 581	10 108	3 919	1 966	4 145 845
1986	9 730	3 807	1 890	8 220	3 188	1 554	10 055	3 921	1 949	4 159 187
1987	9 792	3 924	1 987	8 281	3 294	1 642	10 113	4 035	2 042	4 175 521
1988	9 872	4 063	2 108	8 361	3 423	1 754	10 185	4 168	2 157	4 198 289
1989	9 984	4 239	2 269	8 474	3 589	1 906	10 288	4 335	2 309	4 220 686
1990	10 053	4 377	2 397	8 545	3 719	2 025	10 350	4 468	2 430	4 233 116
1991	10 096	4 495	2 507	8 589	3 826	2 125	10 389	4 582	2 535	4 249 830
1992	10 142	4 620	2 628	8 637	3 941	2 237	10 434	4 706	2 654	4 273 634
1993	10 200	4 761	2 768	8 698	4 074	2 368	10 494	4 850	2 795	4 299 167
1994	10 262	4 911	2 922	8 764	4 216	2 513	10 562	5 007	2 953	4 324 815
1995	10 326	5 069	3 088	8 833	4 366	2 670	10 633	5 173	3 126	4 348 410
1996	10 384	5 226	3 259	8 896	4 515	2 832	10 699	5 340	3 304	4 369 957
1997	10 379	5 327	3 378	8 898	4 609	2 943	10 699	5 446	3 428	4 392 714
1998	10 368	5 425	3 499	8 894	4 700	3 056	10 693	5 551	3 555	4 417 599
1999	10 453	5 623	3 726	8 988	4 893	3 274	10 783	5 756	3 787	4 445 329
2000	10 479	5 770	3 909	9 024	5 035	3 450	10 810	5 906	3 972	4 478 497
2001	10 271	5 688	3 869	8 826	4 949	3 404	10 603	5 826	3 934	4 503 436
2002	10 102	5 644	3 869	8 668	4 900	3 396	10 437	5 788	3 938	4 524 066
2003	9 998	5 664	3 934	8 574	4 916	3 453	10 335	5 813	4 008	4 552 252
2004	9 888	5 681	4 000	8 475	4 927	3 509	10 234	5 841	4 084	4 577 457
2005	9696	5 618	3 989	8 294	4 859	3 489	10 055	5 793	4 088	4 606 363
2006	9389	5 438	3 864	8 000	4 676	3 356	9 763	5 633	3 982	4 640 219
2007	8 997	5 170	3 648	7 622	4 405	3 134	9 386	5 384	3 786	4 681 134
2008	8 672	4 961	3 489	7 314	4 197	2 969	9 073	5 192	3 644	4 737 171
2009	8 220	4 621	3 194	6 882	3 860	2 671	8 626	4 862	3 362	4 799 252
2010	8 030	4 534	3 145	6 715	3 778	2 622	8 429	4 773	3 313	4 858 199
2011	7 803	4 408	3 058	6 512	3 659	2 536	8 203	4 654	3 236	4 920 305
2012	7 464	4 167	2 855	6 200	3 429	2 337	7 855	4 410	3 032	4 985 870
2013	7 111	3 906	2 628	5 877	3 181	2 115	7 493	4 146	2 804	5 051 275
2014	6 816	3 696	2 445	5 616	2 988	1 943	7 190	3 934	2 622	5 109 056
2015	6 605	3 565	2 338	5 443	2 878	1 850	6 971	3 800	2 514	5 165 802
2016	6 529	3 565	2 359	5 405	2 901	1 887	6 881	3 792	2 530	5 213 985
2017	6 542	3 656	2 472	5 456	3 014	2 016	6 880	3 874	2 638	5 258 317
2018	6 446	3 640	2 483	5 395	3 019	2 041	6 768	3 848	2 642	5 295 619
2019	6 245	3 521	2 392	5 229	2 920	1 965	6 547	3 714	2 538	5 328 212
2020	6 168	3 523	2 421	5 190	2 945	2 011	6 447	3 697	2 550	5 367 580
2021	6 225	3 658	2 585	5 284	3 106	2 194	6 469	3 802	2 686	5 391 369

Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

The estimated per capita asset value of Norwegian petroleum resources in constant 2015 prices over the period 1970-2021 and are cross-classified by the rate of return to produced capital and the discount rate are reported in Table A7 in Appendix A. Figure 4.7 displays the estimated results.

The general pattern as shown in Figure 4.7 is similar to those as shown in Figure 4.4 and Figure 4.6. In particular, the estimated asset value per capita in constant 2015 prices as displayed in Figure 4.7 has shown a decreasing trend already starting from the year when the top has reached, depending on the choice of rate of return and the discount rate.

As shown by the last row in Table A7 in Appendix A, the estimated asset value in constant 2015 prices peaks in 1980 and 2000 if the annual real discount rate is chosen as 1% and 4%, respectively. If the annual real discount rate is chosen as 7%, the estimated asset value in constant 2015 prices reaches the top in 2004 except that it tops in 2000 once the annual real rate of return to produced capital is chosen as 7%. A similar pattern is also observed in Liu (2016), although the detailed methods applied in Liu (2016) for measuring the asset value of Norwegian petroleum resources differ from those used in this paper.

A shrinking petroleum resources in per capita terms is not a good sign of sustainability if only petroleum wealth is considered, because one of the important economic resources in Norway is dwindling in the days to come. However, following the weak sustainability criterion, if the resource rent from depletion of this non-renewable resources is entirely invested in produced capital, sustainability is still achievable, according to the so-called Hartwick's rule (Hartwick, 1977).

In accordance with this theory and by learning from the lessons drawn from e.g., 'Dutch disease',[32] the Norwegian government has already decided to set up the GPFG fund, with the purpose to maintain the petroleum wealth that is generated from petroleum extracting activities and to invest the accumulated financial resources into the global capital market, which is a necessary condition for reaching sustainability for a resource-rich country like Norway.

4.5. Revision based on updated information

Up to now, the estimation of the asset value for petroleum resources over the period 1970-2021 is carried out at the beginning of 2021 or the end of 2020 with information being known up to that accounting point. The known information include not only resource rents actually generated during the period 1970-2020, but also the predicted future petroleum production profile from 2021 until 2090.

When moving one accounting year forward, i.e., at the end of 2021 or the beginning of 2022, the actual petroleum production and the generated resource rent in 2021 become known, and a new predicted future petroleum production profile from 2022 onwards will be made available by the Norwegian Ministry of Finance.

Based on the updated information and by means of the same methodology as described so far in this paper, the asset value of petroleum resources over the period 1970-2022 can be estimated. By means of equation (9), the asset value at the beginning of 2022 is estimated first, followed by that at the beginning of 2021, and then by that at the beginning of 2020, and so on.

However, here comes an issue.

[32] The term 'Dutch disease' originates from a crisis in the Netherlands in the 1960s that resulted from discoveries of vast natural gas deposits in the North Sea. The newfound wealth caused the Dutch guilder to rise, making exports of all non-oil products less competitive on the world market.

Because the asset value at the beginning of 2022 or the end of 2021 is estimated based on the updated information, there is no guarantee that the revised estimate for 2022 made at the beginning of 2022 is the same as that implicitly estimated at the beginning of 2021 which is based on the information then. Note that using equation (9), at the beginning of 2021, not only the asset value for 2021, but also those for all future years after 2021 can be estimated, although the estimated results after 2021 are not reported in this paper.

Even more serious, there is guarantee neither that the revised estimates for the period 1970-2021 made at the beginning of 2022 are the same as those estimated at the beginning of 2021, which are based on the information then, i.e., at the beginning of 2021. As a matter of fact, recall that by following equations (7), (8) and (9), a different estimate for 2022 will lead to a different estimate for each year during the whole period 1970-2021, compared with those estimated at the beginning of 2021 for the same period 1970-2021.

Differences between the updated estimates based on the information available at the beginning of 2022 and those at the beginning of 2021 may come from various sources, such as a new and different predicted future unit resource rent, and/or a new and different predicted future production profile due to new discoveries, up- or down-appraisals, catastrophic events occurred in 2021 etc.

Despite differences, it must be accepted that the NPV method is not applied under conditions of perfect foresight. Hence, updating the set of information available to the compiler over an accounting period is inevitable. Thus, it seems plausible that the estimates for the whole period 1970-2021 should be revised based on the updated information formed at the beginning of 2022 or the end of 2021.

Nonetheless, even if revising historical data based on updated information is a good practice in terms of improvement in data quality, a revision taking place each and every year is almost impossible to be accepted by data users. Therefore, revising the historical data should not be implemented, or at minimum, not on an annual basis.

In this paper, it is recommended that although the future resource rents are inevitably changed based on the updated information, the historical estimates are better not to be changed, which are based on the previously formed information set at that time point.

Using our example, the recommended implementation can be carried out as follows: as a first-time establishment, the asset value over the period 1970-2021 is estimated at the beginning of 2021 or the end of 2020, based on information formed at the beginning of 2021 or the end of 2020.

After one accounting year has passed, i.e., at the beginning of 2022 or the end of 2021, the asset value for 2022 is estimated based on updated information formed at the beginning of 2022 or the end of 2021. Therefore, both the estimated resource rents and asset values for 2022 onwards are updated, but the estimates for the period 1970-2021 will not be changed.

After one more accounting year, i.e., at the beginning of 2023 or the end of 2022, the asset value for 2023 is estimated based on updated information formed at the beginning of 2023 or the end of 2022. As a consequence, both the estimated resource rents and asset values for 2023 onwards are updated, but yet, the estimates for the period 1970-2022 will not be changed. The same procedure continues until the end of the service life of the petroleum resources.

As an alternative to the recommendation just described, the historical estimates may be updated, but it has to be done after a rather long period of time such as five or ten years, or synchronized with a benchmark or main revision, depending on the revision policy undertaken in each country.

5. Concluding remarks

As one valuable natural capital, petroleum resources on the Norwegian continental shelf has not yet been registered in the NNA as a non-financial asset as it should be as suggested by the current international statistical standards. Because of limited market transaction, the asset value of Norwegian petroleum resources *in situ* has to be measured by the NPV method, also recommended by the international statistical standards.

From an accounting perspective, this paper documents formally the detailed implementation procedure by applying the NPV method to measuring the asset value of Norwegian petroleum resources in practice. A variety of concrete implementation issues are discussed, and different alternative solutions are accordingly given.

At the beginning of an accounting year such as 2021 as the primary example applied in this paper, for which the asset value is to be measured, a good prediction of future resource rents should be ready, which have to be estimated based on *ex-post*, i.e., actually realized resource rents in the past, otherwise there is no better way to move forward.

Several methods for estimating resource rent are available but it is the residual value method that is considered most suitable in Norway. This method estimates resource rent as a residual, by adding net (of subsidies) specific taxes to, and subtracting user costs of produced capital from, gross operating surplus of the petroleum extraction industry. The data needed for estimation can be directly drawn from the NNA, except for the rate of return to produced capital.

A frequently applied endogenous *ex-post* measure overestimates the rate of return to produced capital and thus two *ex-ante* annual real rates of return, 4% and 7%, are used for resource rent estimation. In addition, a hybrid method, by preserving the *ex-ante* nature but without selecting arbitrarily an exogenous rate of return, is also applied in this paper.

The estimated resource rents over the period 1970-2020 vary across the three chosen rates of return, but the differences between 4% as real rate of return and the estimated nominal rate of return by the hybrid method are small.

The estimated nominal unit resource rent, defined as nominal resource rent per quantity unit, reveals a gradually upward trend over the observed period, but the corresponding real unit resource rent, though volatile, seems to swing around a long-term average. The long-term average in constant 2021 prices over the period 1975-2020 is used as a prediction for the future real unit resource rents.

Applying the NPV method requires the choice of a suitable discount rate. In this paper, it is the individual rather than social discount rates that are applied, because the main purpose of measuring the asset value of Norwegian petroleum resources is to incorporate its value into the balance sheet, so that the principle of market price valuation across different assets is maintained. The 4% and 7% annual real discount rates, previously also applied in the Norwegian studies, are applied. In addition, mainly for the purpose of sensitivity analysis, 1% annual real discount rate is also used.

Using the predicted future real unit resource rent, the chosen annual real discount rate, and a predicted future production profile provided by the Norwegian Ministry of Finance, and following the NPV method, the estimated asset value of Norwegian petroleum resources over the period 1970-2021 at the beginning of 2021 or the end of 2020 can be estimated.

The results show that the estimated asset values are more sensitive to the choice of discount rate than to that of rate of return to produced capital. For each chosen rate of return, when the discount rate increases, the estimated asset value decreases, but the marginal effect is decreasing. In addition, the differences of the estimated asset values by using the different rate of return are decreasing as well, when the discount rate increases. Furthermore, due to price effect, the differences among the estimated asset values by using the different rate of return to produced capital seem to be larger in recent years than in earlier years. This last observation is more visible in the estimated asset values in current prices than in those in constant prices.

By comparing the estimated asset values of petroleum resources in this paper with those of the fixed assets in the whole economy drawn from the NNA, it shows that the average ratio between the two asset categories over the period 1970-2021 is approximately 1.9, 0.8, and 0.5 for the chosen annual real discount rate equal to 1%, 4%, and 7%, respectively, no matter how the rate of return to produced capital is chosen.

Over the period 1970-2021, regardless of the choice of rate of return and discount rate, the estimated asset values of Norwegian petroleum resources in constant 2015 prices and in terms of per capita have already shown a downward trend after tops have been reached.

The implementation of applying the NPV method to measuring the asset value is carried out at the beginning of an accounting year, which is 2021 in this paper. When moving accounting period one year forward, i.e., at the beginning of 2022, the new estimate based on updated information will affect the historical estimates already made at the beginning of 2021. As a reasonably practical solution, it is recommended that the historical estimates are not to be changed, at least not in each and every year.

According to the international statistical standards, sensitivity analysis by using different discount rates should be undertaken if the NPV method is applied for asset value estimation. The varying estimates may be published to provide data users with information on the impact of the choice of discount rate (United States *et al*., 2014). The sensitivity analysis is naturally extended with respect to the choice of rate of return to produced capital, as is carried out in this paper.

Up until now, the final decision about whether to compile and publish the estimated asset value as official statistics is still pending. Regardless of that, if such estimates are needed, several other decisions on the specific choice of both rate of return and discount rate should be made after comprehensive discussions and communications between data compilers and users, as well as among all the agencies at stake. However, as a tentative suggestion, the preference drawn from this paper could be given as follows. The first option may be that annual nominal rate of return is set equal to the estimated one by using the hybrid method as described in this paper, and the annual real discount rate is set equal to 4%. The second option is that annual real rate of return is set equal to 4%, and the annual real discount rate is set equal to 4%. The third option is that annual real rate of return is set equal to 7%, and the annual real discount rate is set equal to 7% as well.

It is worth mentioning that the estimation of petroleum asset value by applying the NPV method is based on a number of assumptions, resulting in uncertainties to some extent to the final estimates. This pure observation justifies the need for further international corporation in harmonizing the way the relevant key assumptions are made for such compilations.

To make the estimated petroleum asset value as reported in this paper more policy-relevant, further analysis on the complied time-series, and in particular, on the changes over consecutive years is needed. Apparently, future research along this line is very much encouraged.

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Appendix A: Supplementary tables

Table A1. Estimated historical nominal resource rent (in current prices, NOK million), 1970-2020

	Using 4% as real rate of return		Using 7% as real rate of return		Using estimated rate of return	
Year	With specific taxes	Without specific taxes	With specific taxes	Without specific taxes	With specific taxes	Without specific taxes
1970	-133	-133	-160	-160	-141	-141
1971	-228	-228	-275	-275	-236	-236
1972	-273	-273	-355	-355	-286	-286
1973	-446	-446	-562	-562	-481	-481
1974	-742	-742	-970	-970	-809	-809
1975	1 331	1 331	960	960	1 309	1 309
1976	2 181	2 082	1 600	1 501	2 281	2 182
1977	1 512	1 455	566	509	1 767	1 710
1978	6 412	6 361	5 323	5 272	6 939	6 888
1979	12 936	12 883	11 609	11 556	13 525	13 472
1980	30 352	30 289	28 599	28 536	31 347	31 284
1981	35 561	35 492	33 252	33 183	36 763	36 694
1982	37 362	37 286	34 382	34 306	38 754	38 678
1983	46 006	45 931	42 517	42 442	47 620	47 545
1984	58 143	58 059	53 951	53 867	59 543	59 459
1985	59 088	58 869	53 975	53 756	60 848	60 629
1986	14 989	14 791	9 045	8 847	18 278	18 080
1987	8 156	7 913	1 161	918	13 221	12 978
1988	-6 353	-6 537	-14 072	-14 256	-509	-693
1989	15 575	15 352	7 250	7 027	20 593	20 370
1990	30 631	30 373	21 900	21 642	34 473	34 215
1991	29 935	28 543	20 636	19 244	32 049	30 657
1992	24 294	21 762	14 191	11 659	24 856	22 324
1993	22 928	20 104	11 895	9 071	21 115	18 291
1994	22 349	19 653	10 776	8 080	20 000	17 304
1995	26 868	23 757	14 763	11 652	23 836	20 725
1996	65 634	61 688	52 832	48 886	64 707	60 761
1997	71 447	67 787	57 648	53 988	70 062	66 402
1998	11 914	8 158	-3 264	-7 020	10 741	6 985
1999	51 194	47 372	34 988	31 166	52 961	49 139
2000	212 796	209 627	195 971	192 802	214 537	211 368
2001	190 885	187 040	173 145	169 300	191 128	187 283
2002	147 564	144 105	129 872	126 413	147 995	144 536
2003	155 608	152 092	137 237	133 721	151 720	148 204
2004	219 346	215 541	200 456	196 651	212 424	208 619
2005	309 220	305 645	288 745	285 170	300 278	296 703
2006	381 789	376 076	359 546	353 833	372 666	366 953
2007	333 720	329 080	308 840	304 200	327 270	322 630
2008	452 773	447 247	424 604	419 078	451 569	446 043
2009	235 989	232 257	204 601	200 869	245 918	242 186
2010	272 655	269 096	239 405	235 846	274 729	271 170
2011	377 957	374 215	341 591	337 849	390 062	386 320
2012	395 403	391 367	355 888	351 852	407 082	403 046
2013	348 186	343 254	304 546	299 614	359 494	354 562
2014	271 745	265 631	223 777	217 663	284 084	277 970
2015	142 479	135 995	92 077	85 593	159 957	153 473
2016	53 576	47 063	3 338	-3 175	71 337	64 824
2017	169 996	163 868	121 330	115 202	190 074	183 946
2018	286 984	280 010	237 221	230 247	311 835	304 861
2019	153 936	147 058	101 949	95 071	183 896	177 018
2020	6 144	-877	-48 756	-55 777	48 937	41 916

Source: Authors' own calculation based on data from Statistics Norway.

Table A2. Production (quantity and value), specific taxes, and total production cost of Norwegian petroleum extraction industry (in current prices), 1970-2020

Year	Production (Sm^3 o. e. million)	Production (NOK million)	Specific taxes (NOK million)	Total production cost (NOK million)		
				Using 4% as real rate of return	Using 7% as real rate of return	Using estimated rate of return
1970	0	0	0	133	160	141
1971	0	61	0	289	336	297
1972	2	266	0	539	621	552
1973	2	354	0	800	916	835
1974	2	853	0	1 595	1 823	1 662
1975	11	4 178	0	2 847	3 218	2 869
1976	16	6 941	99	4 859	5 440	4 759
1977	19	8 299	57	6 844	7 790	6 589
1978	35	14 068	51	7 707	8 796	7 180
1979	45	22 887	53	10 004	11 331	9 415
1980	56	43 618	63	13 329	15 082	12 334
1981	55	53 624	69	18 132	20 441	16 930
1982	55	61 212	76	23 926	26 906	22 534
1983	62	74 286	75	28 355	31 844	26 741
1984	69	91 056	84	32 997	37 189	31 597
1985	73	100 002	219	41 133	46 246	39 373
1986	79	61 875	198	47 084	53 028	43 795
1987	90	61 344	243	53 431	60 426	48 366
1988	98	54 010	184	60 547	68 266	54 703
1989	120	80 244	223	64 892	73 217	59 874
1990	126	98 812	258	68 439	77 170	64 597
1991	139	105 832	1 392	77 289	86 588	75 175
1992	156	107 396	2 532	85 634	95 737	85 072
1993	163	114 452	2 824	94 348	105 381	96 161
1994	184	116 526	2 696	96 873	108 446	99 222
1995	197	122 990	3 111	99 233	111 338	102 265
1996	226	171 282	3 946	109 594	122 396	110 521
1997	234	182 601	3 660	114 814	128 613	116 199
1998	228	132 905	3 756	124 747	139 925	125 920
1999	230	180 120	3 822	132 748	148 954	130 981
2000	241	346 304	3 169	136 677	153 502	134 936
2001	252	332 791	3 845	145 751	163 491	145 508
2002	258	290 090	3 459	145 985	163 677	145 554
2003	262	305 961	3 516	153 869	172 240	157 757
2004	264	369 607	3 805	154 066	172 956	160 988
2005	258	472 955	3 575	167 310	187 785	176 252
2006	249	560 852	5 713	184 776	207 019	193 899
2007	238	535 701	4 640	206 621	231 501	213 071
2008	243	687 655	5 526	240 408	268 577	241 612
2009	240	491 696	3 732	259 439	290 827	249 510
2010	231	543 107	3 559	274 011	307 261	271 937
2011	219	662 959	3 742	288 744	325 110	276 639
2012	225	706 342	4 036	314 975	354 490	303 296
2013	214	685 560	4 932	342 306	385 946	330 998
2014	216	647 901	6 114	382 270	430 238	369 931
2015	228	520 168	6 484	384 173	434 575	366 695
2016	231	427 365	6 513	380 302	430 540	362 541
2017	237	524 431	6 128	360 563	409 229	340 485
2018	227	656 819	6 974	376 809	426 572	351 958
2019	214	536 431	6 878	389 373	441 360	359 413
2020	227	402 933	7 021	403 810	458 710	361 017

Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

Table A3. Estimated nominal marginal revenue and marginal cost (NOK per Sm³ o. e.), 1970-2020

Year	Marginal revenue (NOK per Sm3 o. e.)	Marginal cost (NOK per Sm3 o. e.)		
		Using 4% as real rate of return	Using 7% as real rate of return	Using estimated rate of return
1970	..	..	..	..
1971	169	803	933	826
1972	138	279	322	286
1973	189	428	490	447
1974	424	793	907	827
1975	380	259	293	261
1976	434	299	335	293
1977	432	354	402	340
1978	400	218	249	204
1979	513	223	253	210
1980	775	237	268	219
1981	977	330	372	308
1982	1 116	436	490	410
1983	1 208	461	517	435
1984	1 313	475	536	455
1985	1 367	561	631	537
1986	787	597	673	556
1987	688	597	675	540
1988	552	617	695	557
1989	671	541	610	499
1990	789	545	614	514
1991	771	556	623	541
1992	707	551	616	547
1993	718	577	645	589
1994	649	527	590	540
1995	640	504	565	519
1996	774	484	541	488
1997	797	491	550	497
1998	599	547	613	552
1999	800	577	648	570
2000	1 449	567	636	559
2001	1 338	579	650	578
2002	1 136	565	634	564
2003	1 183	588	658	603
2004	1 413	583	655	609
2005	1 850	650	729	684
2006	2 274	742	831	778
2007	2 275	870	975	897
2008	2 853	989	1 105	994
2009	2 064	1 081	1 212	1 040
2010	2 370	1 188	1 332	1 179
2011	3 049	1 321	1 487	1 265
2012	3 162	1 402	1 578	1 350
2013	3 231	1 602	1 806	1 549
2014	3 023	1 767	1 989	1 710
2015	2 311	1 686	1 907	1 609
2016	1 881	1 649	1 867	1 572
2017	2 241	1 523	1 729	1 438
2018	2 920	1 658	1 876	1 548
2019	2 541	1 821	2 064	1 681
2020	1 806	1 779	2 021	1 590

Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

Table A4. Estimated asset value of Norwegian petroleum resources (in constant 2021 prices, NOK billion), 1970-2021

	Discount rate								
	Using 4% as real rate of return			Using 7% as real rate of return			Using estimated rate of return		
Year	1%	4%	7%	1%	4%	7%	1%	4%	7%
1970	10 690	3 017	1 184	9 088	2 567	1 006	11 048	3 110	1 222
1971	10 798	3 139	1 268	9 180	2 672	1 078	11 160	3 236	1 309
1972	10 908	3 267	1 359	9 275	2 781	1 156	11 274	3 368	1 403
1973	11 020	3 400	1 456	9 371	2 896	1 241	11 389	3 505	1 504
1974	11 133	3 539	1 562	9 469	3 016	1 332	11 507	3 649	1 613
1975	11 250	3 686	1 677	9 571	3 144	1 432	11 628	3 801	1 732
1976	11 354	3 825	1 785	9 660	3 263	1 526	11 735	3 945	1 845
1977	11 454	3 965	1 897	9 747	3 384	1 623	11 839	4 089	1 960
1978	11 560	4 115	2 021	9 841	3 516	1 734	11 947	4 242	2 087
1979	11 642	4 246	2 129	9 912	3 629	1 828	12 031	4 376	2 197
1980	11 695	4 352	2 214	9 954	3 717	1 898	12 084	4 484	2 284
1981	11 674	4 388	2 232	9 924	3 736	1 901	12 063	4 521	2 302
1982	11 648	4 420	2 245	9 889	3 751	1 900	12 035	4 554	2 315
1983	11 628	4 462	2 266	9 863	3 776	1 908	12 015	4 595	2 336
1984	11 590	4 486	2 270	9 819	3 785	1 899	11 975	4 619	2 340
1985	11 522	4 481	2 246	9 746	3 766	1 862	11 907	4 616	2 315
1986	11 461	4 484	2 226	9 683	3 755	1 831	11 844	4 619	2 296
1987	11 534	4 622	2 340	9 754	3 880	1 934	11 912	4 753	2 406
1988	11 629	4 786	2 483	9 849	4 032	2 066	11 997	4 909	2 540
1989	11 760	4 993	2 673	9 982	4 228	2 245	12 118	5 106	2 719
1990	11 842	5 156	2 824	10 065	4 380	2 385	12 192	5 263	2 862
1991	11 892	5 294	2 953	10 116	4 507	2 504	12 237	5 397	2 986
1992	11 946	5 441	3 095	10 173	4 642	2 634	12 290	5 544	3 126
1993	12 015	5 608	3 261	10 245	4 798	2 789	12 361	5 713	3 292
1994	12 087	5 785	3 442	10 323	4 966	2 960	12 441	5 898	3 479
1995	12 163	5 971	3 637	10 404	5 142	3 145	12 524	6 093	3 682
1996	12 231	6 156	3 838	10 479	5 319	3 335	12 602	6 289	3 892
1997	12 225	6 274	3 979	10 481	5 428	3 466	12 602	6 415	4 038
1998	12 212	6 390	4 122	10 476	5 536	3 599	12 595	6 538	4 188
1999	12 312	6 623	4 388	10 587	5 763	3 857	12 701	6 780	4 461
2000	12 343	6 797	4 604	10 630	5 931	4 064	12 733	6 956	4 678
2001	12 098	6 700	4 558	10 397	5 829	4 009	12 489	6 863	4 634
2002	11 899	6 648	4 557	10 211	5 772	4 000	12 294	6 817	4 639
2003	11 777	6 672	4 634	10 100	5 790	4 067	12 174	6 847	4 721
2004	11 647	6 692	4 711	9 983	5 804	4 134	12 055	6 880	4 810
2005	11 421	6 617	4 698	9 770	5 723	4 110	11 844	6 824	4 815
2006	11 060	6 406	4 551	9 423	5 508	3 954	11 500	6 635	4 690
2007	10 598	6 090	4 298	8 978	5 189	3 691	11 056	6 341	4 460
2008	10 214	5 844	4 109	8 615	4 943	3 497	10 687	6 115	4 292
2009	9 682	5 443	3 762	8 106	4 546	3 146	10 161	5 727	3 960
2010	9 458	5 340	3 705	7 909	4 450	3 089	9 928	5 622	3 903
2011	9 191	5 192	3 602	7 670	4 310	2 987	9 663	5 482	3 811
2012	8 792	4 908	3 363	7 303	4 039	2 752	9 253	5 195	3 571
2013	8 376	4 601	3 095	6 923	3 747	2 491	8 826	4 884	3 302
2014	8 028	4 354	2 880	6 615	3 519	2 289	8 469	4 634	3 088
2015	7 780	4 200	2 754	6 411	3 390	2 179	8 211	4 476	2 961
2016	7 690	4 200	2 779	6 366	3 417	2 223	8 105	4 467	2 980
2017	7 706	4 306	2 912	6 426	3 550	2 374	8 104	4 563	3 107
2018	7 592	4 288	2 925	6 355	3 556	2 405	7 972	4 533	3 112
2019	7 355	4 147	2 817	6 160	3 440	2 314	7 712	4 374	2 990
2020	7 266	4 150	2 851	6 113	3 469	2 368	7 594	4 354	3 004
2021	7 332	4 309	3 044	6 225	3 658	2 585	7 620	4 478	3 164

Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

Table A5. Ratio of asset value between petroleum resources and fixed assets in Norway, 1970-2021

	Discount rate								
	Using 4% as real rate of return			Using 7% as real rate of return			Using estimated rate of return		
Year	1%	4%	7%	1%	4%	7%	1%	4%	7%
1970	3.8	1.1	0.4	3.2	0.9	0.4	3.9	1.1	0.4
1971	3.8	1.1	0.4	3.2	0.9	0.4	3.9	1.1	0.5
1972	3.7	1.1	0.5	3.1	0.9	0.4	3.8	1.1	0.5
1973	3.6	1.1	0.5	3.0	0.9	0.4	3.7	1.1	0.5
1974	3.3	1.0	0.5	2.8	0.9	0.4	3.4	1.1	0.5
1975	3.2	1.0	0.5	2.7	0.9	0.4	3.3	1.1	0.5
1976	3.0	1.0	0.5	2.6	0.9	0.4	3.1	1.1	0.5
1977	2.9	1.0	0.5	2.4	0.8	0.4	3.0	1.0	0.5
1978	2.9	1.0	0.5	2.4	0.9	0.4	2.9	1.0	0.5
1979	2.8	1.0	0.5	2.4	0.9	0.4	2.9	1.0	0.5
1980	2.7	1.0	0.5	2.3	0.8	0.4	2.8	1.0	0.5
1981	2.6	1.0	0.5	2.2	0.8	0.4	2.7	1.0	0.5
1982	2.6	1.0	0.5	2.2	0.8	0.4	2.6	1.0	0.5
1983	2.5	1.0	0.5	2.1	0.8	0.4	2.6	1.0	0.5
1984	2.4	0.9	0.5	2.0	0.8	0.4	2.5	1.0	0.5
1985	2.3	0.9	0.5	2.0	0.8	0.4	2.4	0.9	0.5
1986	2.2	0.9	0.4	1.9	0.7	0.4	2.3	0.9	0.4
1987	2.1	0.9	0.4	1.8	0.7	0.4	2.2	0.9	0.4
1988	2.1	0.8	0.4	1.7	0.7	0.4	2.1	0.9	0.4
1989	2.1	0.9	0.5	1.8	0.8	0.4	2.2	0.9	0.5
1990	2.2	0.9	0.5	1.8	0.8	0.4	2.2	1.0	0.5
1991	2.2	1.0	0.5	1.9	0.8	0.5	2.2	1.0	0.5
1992	2.2	1.0	0.6	1.9	0.9	0.5	2.3	1.0	0.6
1993	2.2	1.0	0.6	1.9	0.9	0.5	2.3	1.0	0.6
1994	2.2	1.0	0.6	1.9	0.9	0.5	2.2	1.1	0.6
1995	2.1	1.0	0.6	1.8	0.9	0.5	2.2	1.1	0.6
1996	2.1	1.0	0.6	1.8	0.9	0.6	2.1	1.1	0.7
1997	2.0	1.0	0.7	1.7	0.9	0.6	2.1	1.0	0.7
1998	1.9	1.0	0.7	1.7	0.9	0.6	2.0	1.0	0.7
1999	1.9	1.0	0.7	1.6	0.9	0.6	2.0	1.1	0.7
2000	1.9	1.0	0.7	1.6	0.9	0.6	1.9	1.0	0.7
2001	1.8	1.0	0.7	1.5	0.9	0.6	1.8	1.0	0.7
2002	1.7	1.0	0.7	1.5	0.8	0.6	1.8	1.0	0.7
2003	1.7	1.0	0.7	1.5	0.9	0.6	1.8	1.0	0.7
2004	1.6	0.9	0.7	1.4	0.8	0.6	1.7	1.0	0.7
2005	1.5	0.9	0.6	1.3	0.8	0.5	1.6	0.9	0.6
2006	1.4	0.8	0.6	1.2	0.7	0.5	1.4	0.8	0.6
2007	1.2	0.7	0.5	1.0	0.6	0.4	1.3	0.7	0.5
2008	1.1	0.6	0.4	0.9	0.5	0.4	1.2	0.7	0.5
2009	1.0	0.6	0.4	0.9	0.5	0.3	1.1	0.6	0.4
2010	1.0	0.6	0.4	0.8	0.5	0.3	1.0	0.6	0.4
2011	0.9	0.5	0.4	0.8	0.4	0.3	1.0	0.5	0.4
2012	0.8	0.5	0.3	0.7	0.4	0.3	0.9	0.5	0.3
2013	0.8	0.4	0.3	0.6	0.3	0.2	0.8	0.5	0.3
2014	0.7	0.4	0.3	0.6	0.3	0.2	0.8	0.4	0.3
2015	0.7	0.4	0.2	0.6	0.3	0.2	0.7	0.4	0.3
2016	0.7	0.4	0.2	0.5	0.3	0.2	0.7	0.4	0.3
2017	0.7	0.4	0.2	0.5	0.3	0.2	0.7	0.4	0.3
2018	0.6	0.4	0.2	0.5	0.3	0.2	0.7	0.4	0.3
2019	0.6	0.3	0.2	0.5	0.3	0.2	0.6	0.4	0.2
2020	0.6	0.3	0.2	0.5	0.3	0.2	0.6	0.3	0.2
2021	0.6	0.3	0.2	0.5	0.3	0.2	0.6	0.3	0.2
Mean (1970-2021)	1.9	0.8	0.5	1.7	0.7	0.4	2.0	0.9	0.5
Median (1970-2021)	2.1	1.0	0.5	1.8	0.8	0.4	2.1	1.0	0.5

Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

Table A6. Estimated asset value of Norwegian petroleum resources (in constant 1970 prices, NOK billion), 1970-2021

	Discount rate								
	Using 4% as real rate of return			Using 7% as real rate of return			Using estimated rate of return		
Year	1%	4%	7%	1%	4%	7%	1%	4%	7%
1970	1 044	295	116	887	251	98	1 079	304	119
1971	1 054	307	124	896	261	105	1 090	316	128
1972	1 065	319	133	906	272	113	1 101	329	137
1973	1 076	332	142	915	283	121	1 112	342	147
1974	1 087	346	153	925	295	130	1 124	356	158
1975	1 099	360	164	935	307	140	1 135	371	169
1976	1 109	374	174	943	319	149	1 146	385	180
1977	1 119	387	185	952	330	159	1 156	399	191
1978	1 129	402	197	961	343	169	1 167	414	204
1979	1 137	415	208	968	354	178	1 175	427	215
1980	1 142	425	216	972	363	185	1 180	438	223
1981	1 140	429	218	969	365	186	1 178	442	225
1982	1 137	432	219	966	366	186	1 175	445	226
1983	1 136	436	221	963	369	186	1 173	449	228
1984	1 132	438	222	959	370	185	1 169	451	228
1985	1 125	438	219	952	368	182	1 163	451	226
1986	1 119	438	217	946	367	179	1 157	451	224
1987	1 126	451	229	953	379	189	1 163	464	235
1988	1 136	467	243	962	394	202	1 172	479	248
1989	1 148	488	261	975	413	219	1 183	499	266
1990	1 156	504	276	983	428	233	1 191	514	279
1991	1 161	517	288	988	440	244	1 195	527	292
1992	1 167	531	302	993	453	257	1 200	541	305
1993	1 173	548	318	1 000	469	272	1 207	558	321
1994	1 180	565	336	1 008	485	289	1 215	576	340
1995	1 188	583	355	1 016	502	307	1 223	595	360
1996	1 194	601	375	1 023	519	326	1 231	614	380
1997	1 194	613	389	1 023	530	338	1 231	626	394
1998	1 193	624	403	1 023	541	351	1 230	638	409
1999	1 202	647	429	1 034	563	377	1 240	662	436
2000	1 205	664	450	1 038	579	397	1 243	679	457
2001	1 181	654	445	1 015	569	392	1 220	670	453
2002	1 162	649	445	997	564	391	1 200	666	453
2003	1 150	652	453	986	565	397	1 189	669	461
2004	1 137	653	460	975	567	404	1 177	672	470
2005	1 115	646	459	954	559	401	1 157	666	470
2006	1 080	626	444	920	538	386	1 123	648	458
2007	1 035	595	420	877	507	360	1 080	619	436
2008	997	571	401	841	483	341	1 044	597	419
2009	945	532	367	792	444	307	992	559	387
2010	924	521	362	772	435	302	970	549	381
2011	897	507	352	749	421	292	944	535	372
2012	859	479	328	713	394	269	904	507	349
2013	818	449	302	676	366	243	862	477	322
2014	784	425	281	646	344	223	827	452	302
2015	760	410	269	626	331	213	802	437	289
2016	751	410	271	622	334	217	791	436	291
2017	752	421	284	628	347	232	791	446	303
2018	741	419	286	621	347	235	778	443	304
2019	718	405	275	602	336	226	753	427	292
2020	710	405	278	597	339	231	742	425	293
2021	716	421	297	608	357	252	744	437	309

Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

Table A7. Estimated asset value of Norwegian petroleum resources per capita (in constant 2015 prices, NOK million / person), 1970-2021

	Discount rate								
	Using 4% as real rate of return			Using 7% as real rate of return			Using estimated rate of return		
Year	1%	4%	7%	1%	4%	7%	1%	4%	7%
1970	2.35	0.66	0.26	2.00	0.56	0.22	2.43	0.68	0.27
1971	2.36	0.69	0.28	2.00	0.58	0.24	2.44	0.71	0.29
1972	2.36	0.71	0.29	2.01	0.60	0.25	2.44	0.73	0.30
1973	2.37	0.73	0.31	2.01	0.62	0.27	2.45	0.75	0.32
1974	2.38	0.76	0.33	2.02	0.64	0.28	2.46	0.78	0.34
1975	2.39	0.78	0.36	2.03	0.67	0.30	2.47	0.81	0.37
1976	2.40	0.81	0.38	2.04	0.69	0.32	2.48	0.83	0.39
1977	2.41	0.83	0.40	2.05	0.71	0.34	2.49	0.86	0.41
1978	2.42	0.86	0.42	2.06	0.74	0.36	2.50	0.89	0.44
1979	2.43	0.89	0.44	2.07	0.76	0.38	2.51	0.91	0.46
1980	2.43	0.91	0.46	2.07	0.77	0.40	2.52	0.93	0.48
1981	2.42	0.91	0.46	2.06	0.78	0.39	2.50	0.94	0.48
1982	2.41	0.91	0.46	2.04	0.78	0.39	2.49	0.94	0.48
1983	2.39	0.92	0.47	2.03	0.78	0.39	2.47	0.95	0.48
1984	2.38	0.92	0.47	2.02	0.78	0.39	2.46	0.95	0.48
1985	2.36	0.92	0.46	2.00	0.77	0.38	2.44	0.95	0.47
1986	2.34	0.92	0.45	1.98	0.77	0.37	2.42	0.94	0.47
1987	2.35	0.94	0.48	1.98	0.79	0.39	2.42	0.97	0.49
1988	2.35	0.97	0.50	1.99	0.82	0.42	2.43	0.99	0.51
1989	2.37	1.00	0.54	2.01	0.85	0.45	2.44	1.03	0.55
1990	2.37	1.03	0.57	2.02	0.88	0.48	2.45	1.06	0.57
1991	2.38	1.06	0.59	2.02	0.90	0.50	2.44	1.08	0.60
1992	2.37	1.08	0.61	2.02	0.92	0.52	2.44	1.10	0.62
1993	2.37	1.11	0.64	2.02	0.95	0.55	2.44	1.13	0.65
1994	2.37	1.14	0.68	2.03	0.97	0.58	2.44	1.16	0.68
1995	2.37	1.17	0.71	2.03	1.00	0.61	2.45	1.19	0.72
1996	2.38	1.20	0.75	2.04	1.03	0.65	2.45	1.22	0.76
1997	2.36	1.21	0.77	2.03	1.05	0.67	2.44	1.24	0.78
1998	2.35	1.23	0.79	2.01	1.06	0.69	2.42	1.26	0.80
1999	2.35	1.26	0.84	2.02	1.10	0.74	2.43	1.29	0.85
2000	2.34	1.29	0.87	2.02	1.12	0.77	2.41	1.32	0.89
2001	2.28	1.26	0.86	1.96	1.10	0.76	2.35	1.29	0.87
2002	2.23	1.25	0.86	1.92	1.08	0.75	2.31	1.28	0.87
2003	2.20	1.24	0.86	1.88	1.08	0.76	2.27	1.28	0.88
2004	2.16	1.24	0.87	1.85	1.08	0.77	2.24	1.28	0.89
2005	2.10	1.22	0.87	1.80	1.05	0.76	2.18	1.26	0.89
2006	2.02	1.17	0.83	1.72	1.01	0.72	2.10	1.21	0.86
2007	1.92	1.10	0.78	1.63	0.94	0.67	2.01	1.15	0.81
2008	1.83	1.05	0.74	1.54	0.89	0.63	1.92	1.10	0.77
2009	1.71	0.96	0.67	1.43	0.80	0.56	1.80	1.01	0.70
2010	1.65	0.93	0.65	1.38	0.78	0.54	1.73	0.98	0.68
2011	1.59	0.90	0.62	1.32	0.74	0.52	1.67	0.95	0.66
2012	1.50	0.84	0.57	1.24	0.69	0.47	1.58	0.88	0.61
2013	1.41	0.77	0.52	1.16	0.63	0.42	1.48	0.82	0.56
2014	1.33	0.72	0.48	1.10	0.58	0.38	1.41	0.77	0.51
2015	1.28	0.69	0.45	1.05	0.56	0.36	1.35	0.74	0.49
2016	1.25	0.68	0.45	1.04	0.56	0.36	1.32	0.73	0.49
2017	1.24	0.70	0.47	1.04	0.57	0.38	1.31	0.74	0.50
2018	1.22	0.69	0.47	1.02	0.57	0.39	1.28	0.73	0.50
2019	1.17	0.66	0.45	0.98	0.55	0.37	1.23	0.70	0.48
2020	1.15	0.66	0.45	0.97	0.55	0.37	1.20	0.69	0.48
2021	1.15	0.68	0.48	0.98	0.58	0.41	1.20	0.71	0.50
Mean (1970-2021)	2.08	0.95	0.57	1.76	0.80	0.48	2.15	0.98	0.58
Maximum (1970-2021)	2.43	1.29	0.87	2.07	1.12	0.77	2.52	1.32	0.89

Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.