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The Petroleum Tax Act and Investment Distortions

Did the Norwegian petroleum tax system become more or less distorted after the reduction of uplift in 2013?

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Abstract

In light of Sandmo's (1989) definition of neutrality, the objective of the thesis is to measure investment distortions in the Petroleum Tax Act (PTA) before and after the reduction of investment uplift in May 2013. The study relies on one unified model and applies two different approaches, where the model is based on the research conducted by Lund (1987, 1992). Neutrality is analysed from a governmental point of view with a contingent claims analysis (CCA). This method is consistent with the neutrality properties of Boadway and Bruce (1984) and Fane (1987). Thereafter, neutrality is evaluated from a petroleum industrial perspective applying a discounted cash flow (DCF) method. The effect of the reduced uplift is analysed for a firm outside tax position and a company in tax position. Investment distortions are illustrated by comparing the neutrality properties of the PTA, against the neutral Brown cash flow tax and the Norwegian General Tax Act.

The results show that if companies apply a CCA, they have incentives to overinvest. After the reduction of uplift, the incentives to overinvest have been reduced, and tax revenue has increased. In contradiction, if firms outside tax position use a DCF method the PTA gives incentives to underinvest, and the effect on tax income is uncertain. For a company in tax position, the DCF results show that the PTA is relatively neutral and tax income has increased after the reduction of uplift. This implies it is an advantage to be in tax position, creating barriers to entry from an industrial perspective. Based on these results, we find it likely that the PTA has become more neutral and tax income increased after the reduction of uplift.

Preface

This thesis is written as a final part of our master's degree in Finance at Norwegian School of Economics (NHH) during the spring semester of 2017. The Norwegian Tax Administration and SNF at NHH have awarded this thesis with a tax scholarship.

We would like to thank our supervisors, Dirk Schindler and Floris Zoutman. Thanks to Dirk for good discussions and fast and constructive feedback, and to Floris for feedback and guidance with the development of our model. We are also grateful for contributions from Diderik Lund, on how to formulate our research question and recommendation of relevant literature on petroleum taxation. Finally, we would also like to thank Statoil for taking the time to meet us. The meetings gave us useful insight into the Petroleum Tax Act from an industrial perspective.

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1. Introduction

Petroleum production at the Norwegian Continent Shelf (NCS) started early in the 1970s and has contributed with over 13 000 billion Norwegian kroner to the Norwegian gross domestic product[1]. This makes the petroleum industry the largest in Norway; measured in value added, government revenue, investments and export value. Norway benefits from the petroleum resources by collecting tax via a special tax system; The Petroleum Tax Act (PTA). The aim of this tax regime is to secure that a large share of the realised rent from the extraction of natural resources is channelled to the treasury.

The Ministry of Finance ordered in October 1999 a proposal for a reform of the PTA, where the main objective was to achieve an economical, efficient tax system. In 2000, the *Official Norwegian Report on Petroleum Tax* was presented[2]. The NOU2000:18 report concluded that the petroleum tax regime was too generous, implying that the PTA subsidies petroleum investments. The report suggested to reduce the investment uplift to achieve a neutral petroleum tax system compared to the General Tax Act (GTA). The uplift is supposed to protect the normal return from tax and is an additional deduction after the basis for corporate income tax is calculated. This report has been subject to debate in the later years.

Sandmo (1989) defines a tax system as neutral when the relative probability assessment of various decision options is the same before- and after-tax, irrespective of the tax position. If the tax system is neutral, an investment decision that has a positive net present value (NPV) of cash flows before-tax should also have a positive NPV of cash flows after-tax, and vice versa.

In May 2013, the uplift in the PTA was reduced from 30 percent to 22 percent[3], equally divided over four years. The Ministry of Finance (2013a) argued that the reduction would increase the cost awareness among the petroleum companies and increase tax revenues. The reduction of uplift created considerable controversy in the media. This thesis analyses the effect of the reduction and in particular studies investment distortions.

There are essentially two different, ongoing, debates concerning the neutrality of the PTA. The first debate involves academics criticising the method and assumptions applied by the

[1] See Norsk Petroleum (2017a).
[2] NOU2000:18 – Skattlegging av petroleumsvirksomhet.
[3] In 2017, the uplift was further reduced to 21.6 percent.

government when the neutrality in the PTA is analysed. The Ministry of Finance uses a partial discounting cash flow (PDCF) method when analysing petroleum investments, where value additivity in the PTA is maintained[4] (the Ministry of Finance, 2013b). Osmundsen, Emhjellen, Johnsen, Kemp and Riis (2015) criticise the PDCF method and argue that this approach is impossible to apply, and not in line with industry practice[5].

The other debate concerns the neutrality properties in the PTA regardless of the method applied. Unused tax allowances are refunded in the PTA if the company terminates its NCS activities. Therefore, the government argues that the tax allowances are certain and the required cost of capital should be lower than the average cost of capital, which multinational corporations usually apply[6]. Osmundsen et al. (2015) disagree, and confirms that companies do not consider the tax allowances as certain and that companies apply a higher required cost of capital than the government. Osmundsen et al. (2015) show that the PTA can lead to underinvestment by applying a simple model field.

In addition, some environmentalists have been involved in the debate and argue that the government subsidises the petroleum industry[7]. The industry, on the other hand, claims that the tax system is too strict, leading to underinvestment at the NCS[8]. The purpose of this thesis is to contribute to both debates, considering methods and neutrality. We analyse possible over- and underinvestment and the effect on tax revenue from the PTA.

This thesis answers the following question:
"Did the Norwegian petroleum tax system become more or less distorted after the reduction of uplift in 2013?"

The thesis answers the question in light of Sandmo's (1989) definition of neutrality by applying a model based on the research by Lund (1987, 1992). The model employs an analytical production function which describes and quantify the incentives of any production possibilities for a petroleum field. The scale of development is adjusted optimally, where petroleum companies select the development plan which maximises the expected NPV of profit after-tax. Hence, the model allows to measure the changes in the profit before-tax, profit

[4] See Schall (1972) for the definition of value additivity.
[5] For readers interested in a broader overview of this part of the discussion, see for example Osmundsen and Johnsen (2013) and Lund (2013).
[6] See the Ministry of Finance (2013b).
[7] See Aarsnes and Lindgren (2012).
[8] See Kon-Kraft (2003).

after-tax and tax revenue, after the uplift reduction. If the preferred scale of development differs from the socioeconomic optimal plan, investment distortions occur.

The model applied deviates from Osmundsen et al. (2015) and the Ministry of Finance (2013b), who employ a static model field, without a production function. The limitation of a static model field is that it assumes company behaviour is unaffected by the implementation or changes in taxes. Such a model has only one possible development plan. Therefore, it is not possible to analyse welfare differences between two different tax systems.

The model applies two different approaches; a stochastic contingent claims analysis (CCA) and a deterministic discounting cash flow (DCF) method. The CCA represents the authorities' perspective of neutrality and captures the nonlinearities in the cash flows, as a result of asymmetrical treatment of loss and profit. Risky cash flows are separated from the risk-free tax allowances. The NPV of risky cash flows is found by using risk-neutral[9] prices from the price volatility of the underlying assets; oil and gas. The certain tax allowances are discounted by the risk-free interest rate which is in line with the neutrality properties provided by Boadway and Bruce (1984) and Fane (1987).

Summers (1987) finds that in general companies do not separate cash flows. The common method applied by the petroleum industry is the DCF method[10], where all cash flows are discounted by one uniform cost of capital. This method represents the industrial perspective of neutrality. The DCF method treats cash flows as linear, but it is easy to interpret and understand. The analysis compares the results from the two approaches to examine whether neutrality coincides between the governmental and the industrial perspective.

In both approaches, welfare differences and investment distortions are analysed for a firm outside tax position and a company in tax position at the NCS. By comparing the results, it is possible to determine if the PTA is neutral irrespective of the tax position.

Additionally, companies employ other profitability measurements than the NPV of discounted cash flows. The internal rate of return (IRR) and the materiality criteria are common methods

[9] A risk-neutral investor judge risky projects solely by their expected rates of return. The level of risk is irrelevant, meaning there is no penalty for risk (Bodie, 2014, p. 172).
[10] See also Graham and Harvey (2001), Siew (2001) and BCG (2007).

applied by the industry[11]. How these profitability measurements affect investment decisions are discussed.

Investment distortions are measured against the Brown cash flow tax[12] and the GTA. The Brown tax is chosen due to is neutrality properties[13], and is a good benchmark when analysing distortions in tax systems. The comparison against the GTA makes it possible to determine whether the PTA leads to over- or underinvestment compared to an equal onshore investment. If the capital allocation between onshore and offshore investments are not socioeconomically optimal, it can cause welfare loss[14]. Investment distortions are analysed by comparing the welfare differences in the PTA before and after the reduction of uplift. The welfare differences are analysed in a Ramsey setting from two extreme perspectives[15], where the non-distorting Brown tax is applied as the benchmark. First, company profit after-tax and tax revenue count equally in the welfare function. Second, we assume the government is selfish and is only maximising tax revenue. The tax system with the lowest welfare loss is the preferred one.

The results of the reduced uplift are ambiguous. From a governmental perspective, the analyses show that the tax allowances are too favourable, regardless of the tax position. After the reduction of uplift, overinvestments are reduced and tax revenue increased. From an industrial perspective, the results indicate that a firm outside tax position has incentives to underinvest. The effect on tax income is uncertain, but distortions have increased after May 2013. The results for a company in tax position implies that the PTA are relatively neutral and tax revenue has increased after the reduction of uplift. From an industrial perspective, there are increased barriers to entry, and the tax system is distorted between firms outside tax position and companies in tax position. The results of the DCF analyses are sensitive to the cost of capital. We conclude that investment distortions depend on the method applied, the cost of capital and tax position.

The rest of the thesis is structured as follows. Chapter two presents relevant theory; investment distortions and neutrality, valuation theory and welfare theory are described. Chapter three presents a literature overview. Chapter four describes the design of the PTA 2017, the PTA

[11] Graham and Harvey (2001) find that IRR is a common profitability measurement for investment decisions. Materiality is a potential problem, even if the project has positive NPV it is not conducted due to too low financial volume. Osmundsen et al. (2000) discuss this issue.
[12] Brown (1948) developed a pure cash flow tax which is based on realised transactions.
[13] This is shown in Fane (1987), Bond and Devereux (1995) and Lund (2002).
[14] See Sandmo (1989).
[15] Ramsey considers optimal commodity taxation where tax revenue can be raised with the least amount of distortions (Gruber, 2011).

2013 and the GTA. Chapter five presents the model and the two approaches. Chapter six presents the results and sensitivity analyses. Chapter seven discusses which results we find the most important, the impact of materiality and criticism of model and results. Finally, Chapter eight concludes the thesis, followed by the Bibliography and the Appendix.

Boundaries of the Thesis

Sandmo (1979) argues that governments can have incentives to use taxes as a tool to affect demand, and therefore deviate from the Pareto optimal capital allocation for creating economic stabilisation. Relating this to petroleum investments at the NCS, such incentives can be for environmental or financial reasons. This thesis focuses on the quantitative results of the CCA and the DCF analyses, where it is assumed that the optimal tax system is neutral. Incentives which deviate from the optimal capital allocation, as seen from a governmental perspective, are not further discussed.

The study focuses on the effect of the reduction of uplift. Therefore, the thesis only studies the part of the PTA which consider development and production costs. Area fees, environmental taxes and exploration costs are neglected, and investment distortions, as a result of these factors, are not analysed.

2. Theoretical Framework

This chapter explains relevant theories for the thesis. First, the definition of neutrality is presented with an example of why neutrality is important in a tax system with a high marginal tax rate. Further, the Brown cash flow tax and its neutrality properties are described, before some basic valuation theory is presented. A neutral tax system from a governmental perspective can be distorted due to company behaviour, and such potential distortions are described. Finally, welfare theory is explained, which is applied when measuring welfare differences.

2.1 Neutrality in Tax Systems

Neutrality is defined by Sandmo (1989, p. 310) as the relative profitability assessment of various decision options that are the same before- and after-tax, if not the tax system is distorted. If the profit before-tax is negative (positive) and the profit after-tax is positive (negative), the investment is conducted (rejected), leading to a distortion problem.

Profit is defined as income minus operating costs and capital costs, where capital costs are depreciations plus the alternative costs of holding the assets. Neutrality occurs when the present value of taxable profit is equal to the companies' definition of the present value of profit. There are several reasons why taxable profit and the companies' definition of profit deviate. For example, the cost of holding an asset is difficult to measure, since the lifetime of the asset and the required rate of return vary among sectors, companies and projects. The tax system is therefore only neutral for one specific cost of capital (NOU2000:18, 2000, p. 132). The cost of capital makes it difficult to design an overall neutral tax regime applicable to all investments[16]. Therefore, the tax system is at best, neutral for a project with an average cost of capital. This implies that some investments are over-capitalised and others under-capitalised, depending on the cost of capital employed for that specific project.

2.1.1 Neutrality in High Marginal Tax Systems

This sub-chapter illustrates why neutrality is particularly important in tax systems with a high marginal tax rate, based on a simple example from the Official Norwegian Report (2000, pp.

[16] It is possible with a cash flow tax. See Chapter 2.2.

286-288). First, consider a situation without taxes where the company profit function is given by:

$$\pi = F(C) - C \tag{2.1}$$

where π is the company profit, *F(C)* is a concave function of income, given by *C*, where *C* is the costs[17]. The company maximise profit by setting the first order derivative of *C* equal to zero:

$$F'(C) - 1 = 0 \tag{2.2}$$

If tax is implemented, the income is taxed at rate *t*, and costs are deducted at rate *s*. The new profit function is then given by:

$$\pi = F(C)(1-t) - C(1-s) \tag{2.3}$$

The company maximise profit by setting the first derivative of *C* equal to zero:

$$F'(C)(1-t) = (1-s) \tag{2.4}$$

If taxes and expenses are treated equally, $s = t$, the tax system is neutral. If an expense is deductible, then the equivalent income must be taxable. If *t* and *s* are not equal, the tax wedge is measured by the following formula:

$$\frac{1-s}{1-t} \tag{2.5}$$

This formula is applied for analysing theoretical distortions in tax systems, and to give insight into two important relations. First, the formula shows that if *s* is higher than *t*, companies are too capital-intensive, and if *s* is lower than *t* companies underinvest. Second, distortions increase with the marginal tax rate. For example, if *t* tends towards one, and *s* is higher than *t*, investments goes towards infinity. If *s* is lower than *t*, and *t* tends towards one, investments go towards zero.

Given that $t > s$ by one percentage point, Equation 2.5 shows how a higher tax rate compared to a lower tax rate increase the tax wedge. This is illustrated by an example, where the marginal

[17] This is similar to the profit function used in our model, Equation 5.3.

tax rate in the PTA and the GTA is compared. The tax rates are 78 percent and 24 percent, respectively.

$$\frac{1-(t_{PTA}-0.01)}{1-t_{PTA}} = \frac{1-0.77}{1-0.78} = 1.045 \quad (2.6)$$

$$\frac{1-(t_{GTA}-0.01)}{1-\ t_{GTA}} = \frac{1-0.23}{1-0.24} = 1.013 \quad (2.7)$$

Equations 2.6 and 2.7 imply that one percentage point difference between *s* and *t*, leads to 3.46[18] times higher investment distortions under the PTA, from the Pareto-optimal solution, compared to the GTA. This is an argument that the design of a tax system with a high tax rate requires a more thorough review than a design of a low tax system (NOU2000:18, 2000, p. 288).

2.2 Brown Cash Flow Tax

Brown (1948) introduces a tax regime based on net cash flows. The tax base constitutes of net cash flows before financial items[19]. The cash flow surplus is related to the tax subject's total assets. There are mainly two differences between the Brown cash flow tax definition of surplus and the regular accounting definition. First, interest expenses and interest income are not included in the tax base. Second, the entire investment expense is deducted in the same year as the expense occurs, and not gradually through depreciations.

Positive cash flows are immediately taxed, and the government immediately refunds negative cash flows. The government acts as a passive collaborator in corporations' investments, implying that the government pays a share of the investment expenses, but also gets a corresponding share back of future earnings. Therefore, the Brown tax is a flat tax, and the main benefit is that the IRR is the same before- and after-tax, meaning the tax is neutral[20]. The Brown tax is expressed by Lund (2002, p. 40) as follows:

18 $\left(\frac{1.045-1}{1.013-1}\right)$

19 Financial items include borrowings, repayments, interest expenses and interest incomes.

20 Relating to the section 2.1.1, there is no deviation between *t* and *s*, and the tax rate, τ^k, applies to both payments and deductions.

$$\sum_{i=0}^{T} V(\tilde{X}_t) \gtreqless 0 \leftrightarrow \sum_{i=0}^{T} V\left(\tilde{X}_t(1-\tau^k)\right) \equiv (1-\tau^k) \sum_{i=0}^{T} V(\tilde{X}_t) \gtreqless 0 \qquad (2.8)$$

where *V* is the valuation function and $\tilde{X}_t$ is the cash flows from a project in year *0* to *T*. If the first part of the equation equals zero, the project is exactly marginal (NPV=0). After a Brown tax is levied with the same tax rate, τ^k, in all years, the project is still marginal, and the principle of value additivity is satisfied.

Due to its neutrality properties, the Brown tax is often debated in the public sphere in conjunction with the designing of tax systems of non-renewable resources. The tax system makes it possible to tax non-renewable resources with a high marginal tax rate without creating investment distortions. Irrespectively, this tax system is rarely used, due to several disadvantages (NOU2000:18, 2000, pp. 42-43). Firstly, corporations have strong incentives to cover operational incomes as financial incomes and financial expenses as operational costs, since the tax base is calculated before the financial items are included[21]. Secondly, it can be problematic to add such a tax into tax treaties between countries. Thirdly, the government is exposed to significant refunds in years with negative cash flows, due to low prices of non-renewable resources or substantial investments. Therefore, the Brown tax leads to higher volatility of incomes and outflows for the government, increasing the government risk.

2.2.1 Neutrality to Benchmarks

Sandmo (1989, p. 315) discusses why it is important to implement a neutral tax system to prevent a suboptimal resource allocation. The Official Norwegian Report (2000, pp. 31-34) claims that the GTA is distortive, and leads to under-capitalisation compared to a neutral tax system. To ensure neutrality between the GTA and the PTA, the PTA should be equally distorted as the GTA, compared to a neutral tax system, and is therefore used as a benchmark. It is then possible to analyse if investors allocate too much money or too little to offshore petroleum projects compared to onshore projects, in relation to what is socioeconomically optimal. Additionally, the PTA is measured against a neutral tax, the Brown cash flow tax. The purpose is to analyse the neutrality properties in the PTA compared to a non-distorted tax.

[21] An alternative variation the of pure cash flow tax is proposed by the Meade Committee (1978), where financial items are included in the tax base. In this case, the tax base is related to the company's equity.

As the NOU2000:18 (p.277) suggests, it is also possible to compare the Norwegian PTA against foreign petroleum tax regimes. Neutrality is then measuring if multinational petroleum corporations allocate to much or too little money to Norwegian projects compared to investments abroad. Due to the timeframe, this is not conducted.

2.3 Valuation Theory

Companies maximise shareholders' wealth by accepting projects with positive NPV. If cash flows are risk-free, the process is straight forward. The cash flows are discounted by the risk-free interest rate, only adjusted for the time value of money. When adding risk to a project, the cash flows are uncertain, and the present values of the cash flows are adjusted for the risk.

Discounting Cash Flow Methods

The most common valuation method is a DCF method[22]. The method uses one risk-adjusted cost of capital found by the capital asset pricing model (CAPM), to discount all cash flows if the company is entirely financed by equity[23]. Companies discount cash flows by the weighted average cost of capital (WACC)[24], if the project is financed by equity and debt. The NPV is found as follows:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+k)^t} \tag{2.9}$$

where CF_t is the expected cash flow in year t and k is the WACC.

The PDCF method split cash flows into different streams with various risk. The cash flows are discounted by the risk-adjusted cost of capitals for each cash flow stream, and the NPV is expressed as:

$$NPV = \sum_{t=1}^{n} \frac{CF_{A,t}}{(1+k_A)^t} + \sum_{t=1}^{n} \frac{CF_{B,t}}{(1+k_B)^t} \tag{2.10}$$

where the risk of cash flow A (CF_A) differs from the risk of cash flow B (CF_B) and is discounted by a different cost of capital ($k_A \neq k_B$). The PDCF method is based on the principle of value additivity, which Schall (1972, p. 13) defines as: *"The value of the sum of any set of*

[22] See Summers (1987), Graham and Harvey (2001), Siew (2001) and BCG (2007).
[23] See Sharpe (1964), Lintner (1965) and Mossin (1966).
[24] The WACC is derived from the CAPM and the cost of debt, using the first Miller and Modigliani (1958) theorem.

income streams equals the sum of the individual values of those streams. This additivity property applies whether the streams are debt or equity returns (or combinations thereof) …"[25].

The main limitation with the discounting cash flow methods is that risk is constant over time and equal for all different cash flows. The discounting cash flow methods consider cash flows as linear, and the approaches are therefore not appropriate when tax systems treat profits and losses asymmetrically, leading to nonlinear cash flows after-tax. Asymmetry in tax systems occurs when profit is taxed immediately, while the loss is carried forward and deductible in later years when the profit is positive. Such treatment of loss is asymmetric compared to the profit for two reasons. Firstly, it is not certain that the company will ever be in tax position and make use of the loss carry forward. Secondly, if the company comes in a tax position, the NPV of tax reduction is reduced. For asymmetric tax regimes, stochastic methods, such as a CCA, should be applied (Lund, 1992, pp. 24-25).

Contingent Claims Analysis

The CCA is based on the original Black and Scholes (1973) and Merton (1973) option pricing theory[26]. The original theory is provided for valuing financial options, based on the law of one price. The Black and Scholes formula is later generalised for pricing other securities and assets. The method adjusts for risk in the numerator, unlike the DCF and PDCF, by using the certainty equivalent (CE) of each cash flow of every state. The CE is found by the adjusted probability distribution of risk consideration, using the volatility of some underlying assets. The prices are then considered as risk-neutral and discounted by the risk-free interest rate. The CE are expressed as follows (Ekern & Stensland, 1993, p. 13):

$$P_o = \frac{E_{C_1} - \lambda \sigma_{C_1}}{1 + r_f} \tag{2.11}$$

P_0 is the value of a share in year zero, E_{C_1} is the expected share price in year one, r_f is the risk-free interest rate and σ_{C_1} is the volatility of the share price. λ adjusts the volatility of the share relative to the risk of the stock market and is given by (Ekern & Stensland, 1993, p. 13):

[25] Schall (1972) was the first to introduce the name "value additivity", but the principle was important in earlier research, such as Modigliani and Miller (1958) and Mossin (1969).
[26] The CCA is often referred to as real options or modern asset pricing.

$$\lambda = \frac{E_m - r_f}{\sigma_m^2} \tag{2.12}$$

where E_m is the expected market return and σ_m^2 is the standard deviation of the market portfolio. The $E_{C_1} - \lambda\sigma_{C_1}$ adjustment makes the investor risk-neutral to get the share today or within a year. The value is then discounted by the risk-free interest rate. The CCA theory assumes that an investor receives the same payoff by replicate the portfolio. This is achieved by continuously buying and short selling the underlying asset, and borrowing and lending at the risk-free interest rate (Merton, 1973). If this assumption is not fulfilled, there is an arbitrage opportunity, which is in contradiction with the law of one price. Based on this assumption, the CCA gives the same answer as the discounting cash flow methods, if cash flows are considered linear[27].

In the equations above, the formulas find the value of a share by using the market portfolio, but the equations are also used to determine the NPV of a project. Then, P_0 is the NPV of a cash flow stream and σ_{C_1} is the volatility of an underlying asset, which makes the expected cash flow, E_{C_1}, uncertain. As the PDCF method, the CCA separate cash flows by using several underlying assets for each cash flow stream with different risk. The systematic risk is assumed to be captured by the volatility of the underlying asset. There are mainly two limitations of using CCA in investment decisions. Firstly, it is difficult to find a tradeable underlying asset that measure the systematic risk. This is not available in most sectors. Secondly, the CCA is time consuming to conduct.

2.4 Profitability Compared to Neutrality

In theory, projects with positive NPV are conducted, and projects with negative NPV are rejected. When projects are mutually exclusive, the project with highest NPV is chosen (Berk, 2014, p. 207). If companies follow these investment rules, and there is symmetrical information between the corporations and the government[28], a neutral tax system gives parity between optimal socioeconomic investments and company investments. Still, there are indications that the petroleum industry practice deviates from theory.

[27] See for example Ekern and Stensland (1993, pp. 13-18).
[28] Expected cash flow and systematic risk is the same for the company and the government.

Discussion of Choice of Beta

According to Osmundsen et al. (2015, p. 198), petroleum companies apply a DCF method where the cost of capital is set by the CAPM. Stock market data is used to calculate the systematic commercial risk, measured as the beta in the CAPM. Based on this theory, Osmundsen et al. (2015) find a beta of 0.83, which leads to a nominal cost of capital to be around nine percent after-tax.

Lund (2013, 2014) on the other hand argues that using an international beta is in contradiction with the principle of value additivity. The beta of a project should reflect the systematic risk of that particular project, not the average risk of all company's projects. Lund (2013, p. 16) claims that the systematic risk of a project at the NCS is lower than the average systematic risk for a multinational petroleum corporation, due to the high tax rate and the certainty of tax allowances. Lund (2014, pp. 572-585) further shows how the company beta is adjusted for certain cash flows to capture the principle of value additivity. There are no indications that companies use the method proposed by Lund. If companies use the beta suggested by Osmundsen et al. (2015), they may use a cost of capital higher than the systematic risk, and investment distortions can occur.

Asymmetric Tax Information

From a company perspective tax allowances are uncertain, since there is a risk that the government can change the tax system in the future (Emhjellen & Osmundsen, 2009). Therefore, several academics have argued that companies should add a risk premium on the cash flows from tax allowances[29]. The government argues that tax allowances are certain, and no risk premium is required, since unused tax allowances are refunded if the company terminates its NCS activities. This implies that there is asymmetrical information between the authorities and the companies. If companies add a risk premium to their cost of capital socioeconomic profitable projects can be rejected, due to information asymmetry.

Other Profitability Measurements

Companies apply a variety of different profitability measurements. In addition to discounting cash flows by the cost of capital, hurdle rates and IRR are common methods used for investment decisions[30]. The risk of using these methods is that the required IRR or the discount

[29] See Emhjellen and Osmundsen (2009) and Osmundsen et al. (2015).
[30] In a survey by Graham and Harvey (2001), 75 percent of companies respond that they almost always use IRR and 57 percent use hurdle rates for their investment decisions.

rate is set higher than the correct cost of capital derived from the CAPM[31], which means that commercially and socioeconomically profitable projects may be rejected.

Another possible deviation from theory is the materiality or the financial volume criteria. Materiality implies that a project must be of a certain economic size to be conducted[32] (Osmundsen, Emhjellen & Halleraker, 2000, p. 1). Even if the project has a positive NPV, it is not conducted because it is too small. The problem relating to materiality can be explained by the access to scarce factors, such as competence, human resources and access to capital (pp. 2-3). Firms prefer to use their best human resources on projects that have a significant impact on their market capitalisation (p. 19). For multinational corporations, this may imply that the most competent personnel are placed on projects abroad in countries with a lower tax rate. In such a scenario, the efficiency of extraction at the NCS may go down, or projects with potential positive NPV gets negative NPV and become rejected, both leading to a welfare loss[33].

Today, most petroleum fields at the NCS are mature fields, which may increase the problem of materiality. There are few large oil fields left, so it is more important than ever to be able to extract the socioeconomically optimal volume from every field efficiently. Historically the annual petroleum production in Norway has increased, but after 2004 the production has decreased (Norsk Petroleum, 2017b). The Norwegian Petroleum Directorate (NPD) predicts a stable production in the years to come, but discoveries of new fields and the size of these are crucial. Moreover, leveraging existing infrastructure to realise near-field developments in mature areas will be equally important. Near-field developments can benefit from the already existing infrastructure related to production and transport capacity, hence lowering the volume required for profitable development. In many instances the economic size of such projects is low. If companies apply the materiality principle, socioeconomically profitable projects may be rejected.

However, it is difficult to know how IRR, hurdle rates and materiality affect the total investments at the NCS. Summers (1987, p. 300) argues that companies are rational and is

[31] The most common hurdle rate is a discount rate higher than the cost of capital.
[32] A hurdle rate of maturity can be set as a size of NPV or NPV/investment ratio.
[33] The principle of materiality is one of the main arguments in the Kon-Kraft report (2003) for reducing the marginal tax rate. NOU2000:18 (2000, pp. 20, 265-270) also discusses the impact of materiality.

maximising shareholder wealth by accepting projects with positive NPV. If a project with positive NPV is rejected, another company will conduct it.

To summarise, it is possible that under-capitalisation occurs even if the tax system is neutral from a governmental perspective. The industry claim that they do not apply the PDCF method or adjust their beta and the corresponding cost of capital based on the relative size of tax allowances, as Lund (2013, 2014) suggests. Firms may suffer from asymmetric information compared to the state, resulting in a higher cost of capital requirement. Companies may also use other profitability measurements than NPV, which may lead to rejection of socioeconomically profitable projects.

2.5 Social Welfare

Welfare economics is a tool to study the determinants of well-being, welfare, in a society (Gruber, 2011, p. 44). The determinants are discussed in two steps. First, the social efficiency, or known as the size of the economic pie. This is measured as the net benefits that consumers and producers receive because of their trade in goods and services. Figure 2.1 demonstrates that consumer and producer surplus is maximised when the supply and demand curve intersect, the equilibrium.

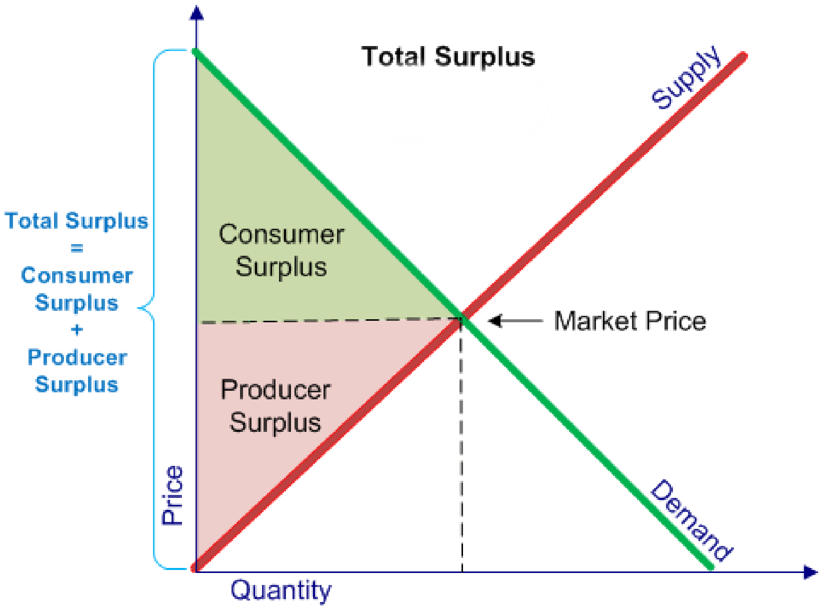


Figure 2.1 Total surplus (Thismatter.com, 2017b)

The second step is to integrate the redistribution, or how the economic pie is shared, into this analysis. It is then possible to measure the total well-being of a society or the social welfare.

For our purpose, the aim is to define welfare in a partial equilibrium model where the weighted sum of rents; the consumer surplus, the producer surplus and the tax revenue, are included. This model is illustrated in Figure 2.2. The weight of producer surplus captures the shadow costs of tax revenue collection or the preference to redistribute.

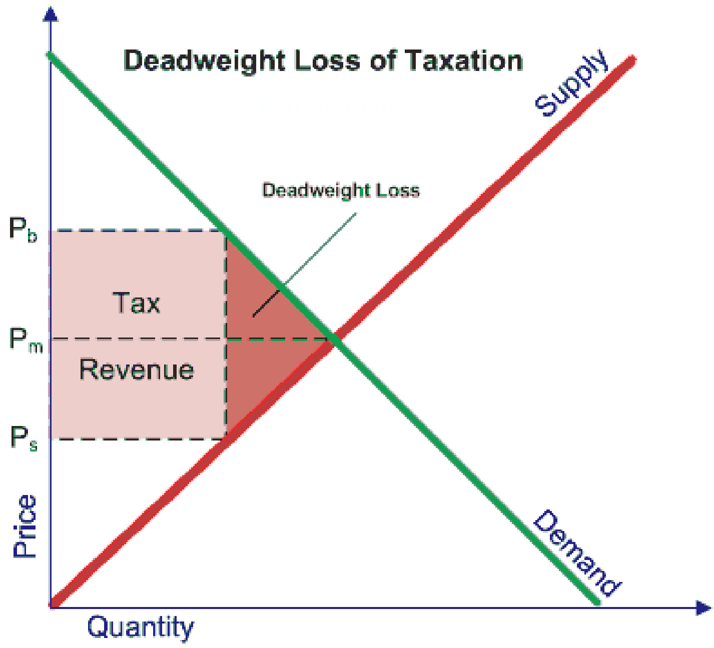


Figure 2.2 Deadweight loss of taxation (Thismatter.com, 2017a)

In Figure 2.2, the implementation of tax changes the market price without tax, P_m, to P_b, the buyer's price, and P_s, the price the seller receives. This reduces demand and supply, resulting in a deadweight loss.

From a normative perspective, the question is how to count for deadweight loss when designing a tax system. In this thesis, two social welfare theories are studied. The first theory was developed by Frank Ramsey in the early 20th century and considers optimal commodity taxation. The aim is to figure out how a given amount of revenue can be raised with the least amount of distortion (Gruber, 2011, p. 601). In a partial equilibrium model with a given sales price, this approach can be approximated by (see, e.g., Haufler, Mardan, & Schindler, 2017, p. 12):

$$W = T + \gamma\pi \tag{2.13}$$

where W is welfare, T is the total tax revenue, π is company profit after-tax and $0 \leq \gamma \leq 1$ is the relative welfare weight placed on the profit. Since the world market determines the sale price, consumer surplus is unaffected by the tax and can be neglected. Hence, the factors considered are tax revenue and firm profits.

The weight on profits shows by how much producer surplus counts for in the social welfare function (Equation 2.13). If $\gamma = 1$, distortions are undesirable and national income is maximised. For $\gamma < 1$, tax revenue comes with distortions and it is optimal to redistribute. For $\gamma = 0$, the government is only interested in maximising tax revenue. Either because the government is selfish, the Leviathan approach (Gruber, 2011, p. 253), or because it follows a Rawls welfare function where the social welfare of a society is based on the well-being of the worst-off person in the society (Gruber, 2011, p. 54). This is the second welfare function analysed.

3. Literature Overview

This chapter presents literature we find important for the thesis. The PTA is based on the neutrality taxation properties of Boadway and Bruce (1984) and Fane (1987), and these theories are presented. Furthermore, literature on different methods to analyse distortions are given. Finally, research on different aspects of the neutrality in the PTA is presented.

3.1 Neutrality Properties for Non-Renewable Resources

Garnaut and Ross (1975) propose a Resource Rent Tax (RRT) scheme. This tax system allows companies to expense the entire investment the same year it takes place. Unlike the Brown tax, negative tax allowances are not refunded by the government but carried forward with interests. Tax allowances carried forward reduces government risk compared to the Brown cash flow tax. From an authority perspective, companies are indifferent to receive the refund immediately or through deductions in subsequent years if the tax allowances are adjusted with interest. According to Garnout and Ross (1975), the interest rate should be the required rate of return employed by the company.

Garnout and Ross (1979, p. 196) points out that the RRT treats taxes asymmetrically. They find that taxes always reduce after-tax profits, but negative outcomes are not subsidised correspondingly. The RRT do not offer a full refund of investments if the income is too small. Mayo (1979) shows more formally that the RRT can lead to distortions. Like the Brown cash flow tax, the RRT may result in problems relating to tax treaties and issues concerning double taxation (Lund, 2002, p. 55).

Boadway and Bruce (1984) generalise the RRT provided by Garnout and Ross (1975). The theory is based on the PDCF method and value additivity. Boadway and Bruce show that scheduling of depreciations over time are equal to the RRT under certainty and is neutral under two critical assumptions. First, depreciations should be equal to 100 percent of the investment. Second, companies deduct the cost of capital of tax assets, which is equal to the nominal cost of capital multiplied by the tax value. The intuition is that corporations are indifferent of deducting investment immediately, as long as they get compensated for the risk. The issue with this tax scheme is that the cost of capital is unique and vary for all projects, making it difficult to implement as an overall tax system. Fane (1987) shows that the tax system proposed by Boadway and Bruce (1984) is neutral under uncertainty if companies are certain that tax allowances are carried forward, adjusted by the risk-free interest rate and refunded if the company terminates.

Emhjellen and Osmundsen (2009) argue that tax allowances are not certain. Firstly, investment costs are uncertain in an investment analysis. Secondly, there is a possibility that the government changes the tax rates and the tax allowances (pp.13-20). Therefore, tax allowances represent a systematic risk. This argumentation implies that the tax system proposed by Fane (1987) distort investments. Tax allowances have to be carried forward with the risk-adjusted cost of capital for this income stream to be neutral.

According to Lund (2001, p. 4), it is not relevant that tax allowances are certain or not, but if the tax allowances are correlated with the market portfolio. He refers to Summers (1987), who finds the correlation between the value of tax allowances and market portfolio to be low. Lund further argues that the correlation is even closer to zero in the PTA (2001, p. 6), since tax allowances are carried forward with the risk-free interest rate, and are refunded by the government if the company terminates its NCS activities. If the correlation between the value of tax allowances and market portfolio are zero, the value of tax allowances should be discounted by the risk-free interest rate. In such a case, the tax system proposed by Fane (1987) is neutral.

3.2 Methods for Analysing Neutrality in Tax Regimes

The valuation methods described in Chapter 2.3 can be applied for analysing investment distortions in different tax regimes. It is common to distinguish between deterministic and stochastic models. Boadway, Bruce, McKenzie and Mintz (1987) apply a deterministic model to analyse the marginal tax return of different projects in Canada, while Kemp (1992) considers whether a marginal project is initiated or not. When tax systems treat profits and losses asymmetrically, leading to nonlinear cash flows after-tax, stochastic models should be applied.

Stochastic models are based on the option pricing theory described in Chapter 2.3. The most common stochastic approach is the CCA. Ball and Bowers (1982) introduce a CCA when they find the effect of uncertainty of the market value on a single given petroleum project. They show that the RRT provided by Garnaut and Ross (1975) are non-neutral under uncertainty.

Lund (1987) creates a model to analyse distortions in the Norwegian PTA by applying Monte Carlo simulations, where the model allows the scale of development to adjust optimally. The model is published in his research paper in 1992. The timing of investments and the shape of production profile remain fixed in prior. The model neglects exploration costs, which is assumed to be sunk cost. Lund (1992, p. 28) finds that the incentives in the Norwegian PTA 1980 reduce investment level by approximately 50 percent, and the resource rent is reduced by 25 percent, compared to the Norwegian PTA 1987.

Mackie-Mason (1990) and Blake and Roberts (2006) apply the model developed by Lund. Mackie-Mason implements some minor model changes. He adds the opportunity to halt production if prices drop sufficiently and re-start if prices rise. Shutdown and reopening have a fixed cost, maintaining the field during these periods have a flow cost, and the firm can abandon the field at zero cost. Mackie-Mason applies the model to analyse how taxes and changes in taxes may affect companies' behaviour under uncertainty. Blake and Roberts apply Lund's model on five different petroleum tax systems and find large differences of distortions among the various regimes.

Unlike Lund, Zhang (1997) develops an irreversible model of oil development where the timing of development is flexible, but the scale of development is held fixed. He uses stochastic prices, which ensure a positive value of waiting. The company is assumed to delay the initial development based on real options values. Zhang (1997, p. 1109) shows that the British Petroleum Revenue Tax requires a unique level of uplift to ensure neutrality with respect to timing.

Smith (2014) creates a *"parsimonious model"* to analyse distortions and tax avoidance in petroleum tax regimes for exploration and development. The parsimonious model is the first model where the scope of exploration, the scale of development and timing are implemented. The model also adds the opportunity to develop secondary or enhanced recovery operations and ultimately abandon a field. Smith's model is probably the most realistic one when analysing distortion effects in petroleum tax regimes, considering how companies make investment decisions under uncertainty. The main limitation of this approach is that it takes a deterministic view of future petroleum prices and ignore the impact of risk[34] (p. 141).

[34] For a broader literature overview, of how to analyse neutrality for high marginal tax systems, see for example Lund (2009) and Smith (2013).

3.3 Distortions in the Petroleum Tax Act

Neutrality in the PTA

The NOU2000:18 report (2000) analyses the neutrality properties in the PTA and concludes that the PTA is too generous, implying that companies have incentives to overinvest at the NCS. The report (p. 132) argues that the uplift should be reduced to two percent, or the deduction profile of depreciation should match the actual lifetime of the investment to ensure neutrality. However, the report underlines that it is only a “calculated neutrality”. It is only neutral under the chosen assumptions regarding tax rates, the required rate of return, inflation and the lifetime of the investment. If one, or more, of these factors changes, the PTA distort investments, and at least one of the tax parameters has to be adjusted to ensure neutrality.

Osmundsen et al. (2015) findings are in contradiction to the NOU2000:18 report (2000). They argue that the tax system is neutral when the IRR is the same before- and after-tax. By using a model field, Osmundsen et al. (2015) show that the PTA gives incentives to underinvest with an IRR significantly higher before- than after-tax. Further, Osmundsen at al. (2015, p. 201) find that the IRR falls from 15.3 percent before-tax to 8.1 percent after-tax if the uplift is reduced to two percent as the NOU2000:18 report (2000) suggests. Osmundsen et al. (2015) conclude that the after-tax profit is substantially lower after the reduction of uplift, and projects that were socioeconomically profitable before the reduction can be shelved, leading to underinvestments at the NCS.

The Kon-Kraft report (2003) argues that the tax burden under the PTA is too high, leading to underinvestments from an industrial perspective. The report suggests that the marginal tax rate should be reduced for new discoveries, to ensure that multinational corporations get incentives to invest at the NCS. The main argument is that the NCS is in a mature phase, where the financial volume may be too low for new discoveries to be developed.

Aarsnes and Lindgren (2012) find that the Norwegian government subsidises the petroleum industry in Norway by too favourable depreciations and uplift rules. Lund (2012) is critical to the calculations by Aarsnes and Lindgren (2012). Lund argues that the report focuses on separate parts of the tax rules and do not analyse the PTA as a complete tax system, where favourable depreciation rules are not considered in context with the high marginal tax rate.

Discussion of Method

The Ministry of Finance (2013b) uses a PDCF method to show that the PTA is neutral, by separating risky cash flows from risk-free tax allowances, which is in line with the neutrality properties of Boadway and Bruce (1984) and Fane (1987). Osmundsen and Johnsen (2013) and Osmundsen et al. (2015) criticise the Ministry of Finance for applying a PDCF method in their neutrality calculations. Osmundsen and Johnsen (2013, p. 13) claim that tax allowances are not risk-free, especially after the reduction of uplift. Furthermore, they state (2013, p. 15) that it is not appropriate to apply a PDCF method since it is not possible to find the systematic risk of each cash flow stream in the market. Therefore, the neutrality properties should be based on the method applied by the industry, the DCF method. Lund (2013) responds to Osmundsen and Johnsen (2013). Lund argues that Osmundsen and Johnsen (2013) calculate incorrectly and the method suggested by the Ministry of Finance is recommended by scholars in valuation literature.

4. Taxes

This chapter describes the purpose of taxes, the importance and reason behind the implementation of the PTA. The design of the PTA 2017, the PTA 2013 and the GTA are then described in detail. The main references used in the following chapter are the PTA (Petroleumsskatteloven, 1975), the GTA (Skatteloven, 1999) and the Official Norwegian Report (NOU2000:18, 2000) and they are not referenced continuously.

4.1 Introduction to Taxes in General

Designing a well-functioning and efficient tax regime is difficult. When designing a tax system, it is necessary to keep in mind the different aspects of taxes and that they, in many cases, are in contradiction to one another. How to best balance between an efficient, fair and user-friendly tax system can often lead to problems. The scope of the Norwegian tax system is to cover community expenses, correct market failure, smooth out the economic imbalances in the population and influence the economic behaviour of the citizens. A working tax system foster investments that are economically efficient, which means that the after-tax return corresponds with the pre-tax return; the socioeconomically return, and companies invest where the return is highest (Store Norske Leksikon, 2015).

The Importance of the Petroleum Tax Act

The PTA was introduced in 1975 and is meant to secure Norwegian ownership of petroleum resources in such a way as to benefit the entire Norwegian population[35]. The PTA covers offshore activities in relation to extraction, processing and pipeline transportation of petroleum. The marginal tax rate for petroleum is 78 percent, which includes a corporate income tax of 24 percent and an RRT of 54 percent[36]. The government has designed the PTA with a high marginal tax rate, where the aim is to capture the resource rent, to ensure that the petroleum resources at the NCS benefit the Norwegian society.

The RRT is well suited for petroleum taxation. Company behaviour is not affected if the resource rent is taxed by a neutral tax[37]. Hence, no efficiency loss occurs (The Ministry of

[35] The income from the PTA accounted for around 13 percent of the Norwegian National Budget in 2016 (Norsk Petroleum, 2017a), this is considerably lower than 2015 due to the drop in oil and gas prices.
[36] The RRT is supposed to capture the economic rent defined as return above the normal return or the required rate of return on invested capital. The normal return is then shielded from the RRT (NOU2000:18, 2000, pp. 43-44).
[37] Resource rent is further referred to as the special tax.

Finance, 2012-2013, pp. 10-16). The problem is that the high marginal tax rate makes it difficult to obtain a tax system that ensures neutrality. Unless taxes are neutral, a high marginal tax rate increases distortions and consequently have an adverse effect on investment behaviour (over- or underinvestment)[38].

4.2 The Petroleum Tax Act

This sub-chapter present the most important elements of the PTA. The table below illustrates how the petroleum tax is calculated, based on the PTA.

	Operating income (based on the norm price)
-	Operating expenses
-	Linear depreciation for investments (over six years from the year the expense occurs)
-	Exploration costs
-	Environmental taxes (NOx and CO2)
-	Area fees
-	Net financial costs
-	Loss carry forward (with interests – risk-free after-tax)
=	**Ordinary tax base (24%)**
-	Uplift (5.4% of historical investment cost for four years – in total 21.6)
-	Excess uplift from previous years (with interests – risk-free rate after-tax)
=	**Special tax base (54%)**

Table 4.1: How to calculate the PTA

Petroleum companies pay environmental taxes, but if they emit more than their allocated quota they must buy extra emission allowances. The companies also need to pay an area fee, which is supposed to ensure that the allocated areas are explored in an efficient way. In 2016, the environmental tax and area fee accounted for around five percent of the total petroleum income to the Norwegian State (the Ministry of Finance, 2017). We do not include them in our analysis, due to the negligible impact these taxes and fees have on the main result.

Norm Pricing

The Petroleum Price Board sets the tax reference prices of oil, the norm price, for the calculation of taxable income from petroleum companies operating at the NCS. The norm

[38] See Chapter 2.1.1.

price is supposed to reflect the price that would have been observed between two independent parties. This rule has been implemented to avoid tax adjustments, for example, a parent company who sells petroleum at a discounted price to a subsidiary abroad. The tax income to Norway, without a norm price, would have been reduced in such a scenario. The norm price is set after every quarter, and normally every type of crude oil gets a specific price (Regjeringen, 2016).

Depreciation

The depreciation rate in the PTA is linear for six years, 16 2/3 percent per annum, from the year the expense occurs. The expenses that fall under this paragraph are acquisitions of pipelines, production facilities and installations that are part of or associated with production installations. Exceptions are made for individual liquid natural gas plants (Snøhvit) in Finnmark and four municipalities in Troms county, where the depreciation rate is 33 1/3 percent per year, for three years.

Fixtures on land, administrative buildings, vehicles, etc. are depreciated using the usual balance rules in the GTA, §§ 14-30 to 14-48, although they are fully utilised in the company's offshore operations. There are often some problems when trying to distinguish if the assets belong to the depreciation rules in the PTA or the GTA.

For offshore assets, the start time of depreciations is more favourable than under the GTA. Offshore investments can be depreciated already from the year the investment is conducted, while onshore investments follow the GTA and cannot be depreciated before it is ready to use.

Deficit

Deficits related to extraction and pipeline transport can be carried forward indefinitely. Moreover, deficits which occurred in the fiscal year of 2002 or later can be carried forward with interest. Unused deficits are refunded by the state if the company terminates its NCS activities. The interest rate is calculated separately from deficits in ordinary income and special tax. The interest rate is based on the Norwegian Treasury Bill with 12-month to maturity plus 0.5 percent and adjusted by one minus the corporate income tax rate, τ_{CIT} (Skatteetaten, 2015). Mathematically this is expressed as follows:

$$Interest\ for\ deficit\ =\ (12\text{–}month\ Treasury\ Bill + 0.5\%) * (1 - \tau_{cit}) \tag{4.1}$$

Uplift

Uplift is a deduction related to investments of fixed assets, if the investment is affected by the special tax. In 2017, the uplift rate was changed from 5.5 percent to 5.4 percent. The change only affects new investments conducted in 2017 or later; previous investments keep the old rate. The uplift rate is 5.4 percent of the cost price of the asset for four years, a total of 21.6 percent. The company pays regular corporate income tax, but before the special tax is calculated the uplift is deducted. The purpose of the uplift is to shield the companies' normal return from the special tax. Unutilised uplift is carried forward with interest (Equation 4.1) and can be deducted in later years. There are no time limits, and it is possible to get a refund of unutilised uplift if the company terminates its NCS activities.

Exploration Costs

The taxpayer may claim the tax value of direct and indirect exploration costs, excluding financial expenses, in the year the cost occurs, from the Norwegian State. The tax value claimed cannot exceed the annual loss in ordinary income at the NCS and in the special tax base. The tax value of the exploration costs is determined by multiplying the deductible cost in the ordinary income and the special tax base by the relevant tax rates for the year the exploration costs are incurred. This means that the taxpayer can get 78 percent of the exploration costs refunded immediately[39]. The exploration cost reimbursement is a unique arrangement. This scheme lowers the barrier to entry for new companies at the NCS, since they do not need to buy producing fields to compete on the same level as established companies in tax position.

Deduction of Financial Cost

Thin capitalisation has been an issue when designing the PTA. The latest change was made in 2007 and distinguishes between interest rate and gains/losses relating to conventional interest-bearing loans and other financial items.

Net financial costs incurred on interest-bearing debt are deductible. These costs include the sum of interest costs and foreign exchange losses, minus foreign exchange gains, relating to such debt. The deductible is equal to the proportion of the net financial costs of the firm, which corresponds to 50 percent of the ratio between the tax value of assets, net of the tax depreciation per 31 December of the tax year, connected to the NCS and the average interest-

[39] The refund is often referred to as a Brown tax element.

bearing debt over the tax year. A corresponding amount of the net financial income should be documented as income if foreign exchange gains exceed the sum of interest costs and foreign exchange losses related to the interest-bearing debt.

This implies that the petroleum companies do not have incentives to use debt for tax reasons, if new debt and equity have the same risk. Interest expenses and currency losses/-gains on interest-bearing debt are deducted by 50 percent of the end-of-year tax specified asset value offshore divided by interest-bearing debt. Mathematically, this is expressed as follows:

$$\mathit{Shelf\ deductions} = (\mathit{Interest\ expenses} \pm \mathit{currency\ losses/{-}gains\ \ on\ interst{-}bearing\ debt}) * \frac{50\%\ \mathit{tax\ assets\ on\ the\ shelf}}{\mathit{average\ interest{-}bearing\ debt}} \quad (4.2)$$

All other financial costs are recorded in the onshore financial statement and are taxed/deducted with a 24 percent corporate income tax. If there is a loss onshore, due to negative financial income, this loss is transferred back offshore, but only for the corporate income tax. Distinguishing between offshore and onshore financial costs can be problematic in the tax statements.

Clean-Up Cost

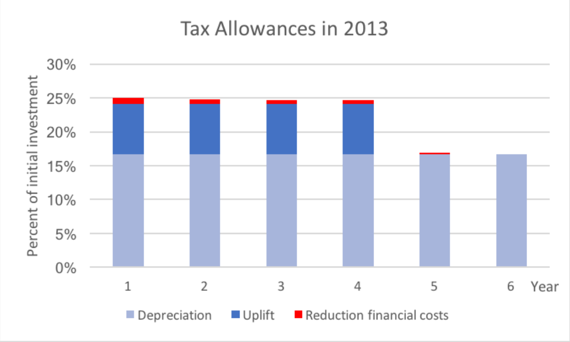
When removing facilities used in production, processing and pipeline transportation at the NCS, the expenses are deductible. The deduction is given when the removal is taking place.

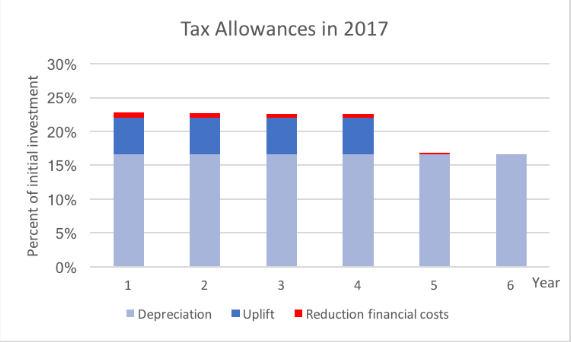
4.3 The Petroleum Tax Act in 2013

The PTA 2013 is almost identical to the PTA 2017, except the difference in uplift and the allocation between corporate and special tax. Before May 2013, the uplift was 7.5 percent per annum divided over four years, 30 percent in total. The corporate income tax was 28 percent and the special tax 50 percent.

Differences in Tax Allowances

The graphs below illustrate the differences in tax allowances between the PTA 2013 and the PTA 2017. The tax allowances are 2.1 percentage point lower each year between year one and year four in 2017 compared to before May 2013. After year four, the tax allowances are equal in the two systems. The graphs also show that the financial tax deductions are relatively small compared to the depreciations and uplifts.





Graph 4.1: Differences in tax allowances

4.4 The General Tax Act

The onshore tax system is based on the Norwegian GTA, where profit is taxed by 24 percent. There are several differences between the GTA and PTA when it comes to how depreciation, net financial cost and loss carry forward are treated in the tax statement. The taxable depreciations in the GTA apply a declining balance method, where the depreciation rate is decided by which balance group the assets represent. Petroleum assets are not included in the GTA, but § 14-43 e includes assets as ships, vessels and rigs with a declining balance ratio of 14 percent per year. We assume this group to be the closest for petroleum assets with respect to lifetime and risk.

For onshore companies, financial income is taxable and financial cost deductible. This gives incentives to use debt compared to equity. Negative profit is carried forward, and reduce the payable tax in years with profit. Unlike the PTA, the GTA does not adjust loss carry forward with interest. When a company onshore terminates, if there is an uncovered deficit which has occurred in the year of termination, the predetermined tax for the previous two years should be altered. In the income for these years, there will then be given a deduction for the uncovered deficit. If the deficit occurred in the year preceding the termination year, the fixed tax for the previous year would be changed accordingly.

5. Model

The thesis relies on one unified model and applies two different approaches. The two methods reflect neutrality from a governmental and industrial perspective. The main objective of this chapter is to explain the structure and design of the model, as well as the two different methods. Furthermore, assumptions and simplifications are described in detail and summarised at the end of the chapter.

5.1 Choice of Model

The thesis applies a model based on the research by Lund (1987, 1992). The model assumes that a company decides the scale of development based on a concave production function, by maximising the expected profit after-tax. If the preferred scale of development differs from the socioeconomic optimal plan, investment distortions occur. Company behaviour may adjust if the tax system is changed, captured by the analytical production function. It is then possible to compare the social welfare between different tax regimes. Investment distortions are measured as the welfare differences of the change in profit before-tax, tax revenue and company's profit. This approach is superior to a simple model field, without a production function, since companies are not able to adjust optimally. Irrespectively of a change in the tax systems, the static model field has only one possible investment plan.

The government evaluates neutrality of the tax system according to the neutrality properties of Boadway and Bruce (1984) and Fane (1987), where tax allowances are considered certain and discounted separately from risky cash flows. In contradiction to Boadway and Bruce (1984) and Fane (1987) which apply a PDCF method, a CCA is chosen in this thesis. The CCA is preferred over the PDCF method since it is hard to find the systematic risk of each cash flow stream in the PDCF approach[40]. In the CCA the systematic risk is found by the volatility of the underlying assets, which is observable in the market.

Osmundsen and Løvås (2009, pp. 15-17) find the PTA to be relatively symmetric and cash flows relatively linear. Some asymmetry occurs since tax allowances are carried forward with interest (Equation 4.1), while the cost of carrying the tax allowances forward is the same as the risk-free ten-year Norwegian Government Bond. Tax allowances are carried forward with

[40] Osmundsen et al. (2015, p. 200) claim the PDCF is not appropriate and argue that there is no theoretical way to observe the systematic risk of each cash flow stream in the stock market.

approximately three percent, found from Equation 4.1[41]. Three percent is lower than the risk-free ten-year Norwegian Government Bond of four percent and implies some asymmetry of loss offset in the PTA, leading to nonlinearity in the cash flows after-tax[42]. Even if the tax wedge seems small, the asymmetric treatment of loss offset may have a significant impact on investment decisions in a tax system with a high marginal tax rate[43]. To capture the nonlinearities in the PTA, the NPV of all possible scales of development are simulated at least 100,000 times with stochastic petroleum prices. The company is then expected to choose the investment level that maximises the average risk-adjusted cash flow after-tax over the different simulations.

In contrast, the most common method applied by the petroleum industry is the DCF method[44]. Therefore, a DCF approach measures neutrality from an industrial perspective in this thesis. The required rate of return is found from the beta observed in the stock market. This implies that companies do not adjust the cost of capital based on the certainty of tax allowances. The assumption is in contradiction to the suggestion by Lund (2013, 2014), the principle of value additivity and the neutral taxation properties of Boadway and Bruce (1984) and Fane (1987).

5.2 The Model

Lund (1987, 1992) computes a typical average profile of a petroleum field based on 33 operating petroleum fields in the British and Norwegian sectors of the North Sea. The theoretical field allows the company to decide the scale of development while timing remains fixed. The scale of development is chosen optimally, and the timing of the decision is therefore neglected. A development plan describes the development of investments, operating costs, clean-up costs and the extraction rates. The development plan has a lifetime of 22 years. The scale of development is determined in year zero, and the company has no opportunities to affect the initial development plan after this decision. After 22 years, the company terminates its NCS activities. Our model uses the same production function and development plan as Lund (1987,1992).

One improvement made in our model is the implementation of gas as a second-factor price. Lund neglects gas in his analysis. However, this has a minor impact on Lund's results where

[41] (3.5%+0.5%)*(1-0.24) = 3.04% in 2017.
[42] The assumptions are described in Chapter 5.2, under Assumptions and Simplification in the Model.
[43] This is further described in Chapter 2.2.1.
[44] See Summers (1987), Graham and Harvey (2001), Siew (2001) and BCG (2007).

oil accounted for around 85 percent of the total export value of petroleum produced at the NCS in 1992 (SSB, 2017). In 2016, 55 percent of exported petroleum values came from oil, the rest from different gas products (SSB, 2017). Gas is implemented to increase the realism of the model, due to the change of impact.

Quantity

The production field is one-dimensional, meaning that all costs for all years are scaled up by the same factor. The adjusted present value (APV) of produced oil barrels is found by the production function (Equation 5.1), where the function has a decreasing return to scale:

$$Q_o = AC^B \tag{5.1}$$

where Q_o is $\sum_{t-1}^{n} q_{o,t} e^{(-yt)}$, $q_{o,t}$ is the production quantity of oil barrels in year *t* and *y* is the net convenience yield[45]. The formula implies that the quantity of oil, Q_o, is the APV of quantity, given in million barrels in year zero. The quantity in year t is discounted to year zero by the net convenience yield. Lund (1987, 1992) finds the present value of costs, *C*, at time zero, by discounting the expected costs of a field by the risk-free interest rate. *C* is divided into investments, operational costs and clean-up costs found in the development plan (Table 5.1). *A* and *B* are positive constants. *B* is a number less than one, which ensures decreasing returns to scale within the given petroleum field, and is, as in Lund (1987, p. 58), set to 0.55. Lund (1987, p. 58) sets *A* to be 0.065944. In 1987, when Lund measured these factors, the petroleum prices were lower than today's prices[46]. In this thesis, *A* is reduced to 0.0244505. A lower *A* ensures that the field size is approximately the same as when Lund measured the theoretical field in 1987. If *A* is not reduced, quantity increases, implying that the fields at NCS are larger than in 1987. A lower *A* ensures that the cost per oil barrel produced reflects the increased costs at the NCS, during the period 1987 and 2017. Hence, the theoretical field is closer to a real petroleum field in 2017.

The number of produced oil barrels, from the production function (Equation 5.1), is used to find the quantity of natural gas. Oil is sold in barrels and gas in millions of British thermal units (MMBtu). When applying the production function, oil barrels are first converted to oil

[45] Convenience yield is the benefit of holding the underlying assets instead of a future contract or a derivative. Net convenience yield = convenience yield - storage costs.
[46] Lund (1987, 1992) sets the oil price to $15 per barrel.

volume, then to gas volume and finally to MMBtu[47]. NPD (2017b) reports that in 2016 around 40 percent of the petroleum volume came from oil and 60 percent from natural gas, which is the ratio applied in the model. The conversion implies that one million oil barrels are equal to 8.418 billion Btu. The formula, for the APV of gas quantity, Q_g, is expressed as:

$$Q_{g} = 8.418AC^{B} = 8.418Q_{o} \tag{5.2}$$

Profit Function

Based on the replication portfolio option pricing theory from Merton (1973), investors may replicate the expected profit by continuously buying and short selling the underlying petroleum assets in the spot market by borrowing and lending at the risk-free interest rate[48]. This implies that the spot price in year zero, P_0, can be used to find the expected APV of profit. Additionally, the quantity, Q_o and Q_g, is the APV of quantity, and C is defined as the APV of costs in year zero. The expected NPV of profit is then given as (Lund, 1987, p. 55):

$$\Pi = P_{0,o}Q_o + P_{0,g}Q_g - C = P_{0,o}AC^B + 8.418P_{0,g}AC^B - C \tag{5.3}$$

where π is the NPV of profit before-tax in year zero. Equation 5.3 is further referred to as the profit function. The company maximises profits by setting the first-order derivative of Equation 5.3 with respect to C equal to zero:

$$\pi(C)' = BP_{0,o}AC^{B-1} + 8.418BP_{0,g}AC^{B-1} - 1 = 0 \tag{5.4}$$

Solving Equation 5.4[49], the optimal scale of development is $6,999,992, approximately equal to $7,000 million, further referred to as the socioeconomic optimal development plan. The NPV of company profit is found by setting the optimal scale of cost, C, into the profit function (Equation 5.3). The NPV of profit before-tax is approximately $5,727 million.

The $7,000 million development plan is chosen if a proportional cash flow tax, such as the Brown cash flow tax, is implemented[50]. The profit after-tax with a Brown tax is given as:

$$\Pi_0 = (P_{0,o}AC^B + 8.418P_{0,g}AC^B - C)(1-\tau) \tag{5.5}$$

[47] See Appendix 10.4 for a conversion table and an example over the conversion details between oil and gas.
[48] It is also possible to find the profit function by assuming the absence of arbitrage opportunities as Black and Scholes (1973). Note that the replicating portfolio is only used to find the expected risk-adjusted profit and companies are assumed to sell the quantity in the spot market.
[49] Using a oil price of $60 per barrel and a gas price of $3.5 per MMBtu. Further, explained at p. 40.
[50] This is further explained and showed in Chapter 2.2.

where τ is the proportional tax rate. With a tax rate of 78 percent, equal the marginal tax rate in the PTA, the tax income to the government, T, is $4,467 million and NPV of company profit after-tax, π, is $1,260 million. These numbers are further employed when analysing the welfare differences in Chapter 6.

Cash Flows Before-Tax in the Model

The development plan is based on the research by Lund (1987, 1992). Table 5.1 shows the development plan. The development plan decides the distribution of the present values of cost between investments, operational costs and clean-up costs, and the distribution of these expenses for each year. Investments and operational costs have a one-to-one relationship, while clean-up costs are set to 12.5 percent of investments. This implies that 47.05 percent of costs, C, are investments[51], 47.05 percent operational costs and 5.9 percent clean-up costs. These are used as constants in the Equations 5.7 to 5.9.

Year (t)	Investments ($F_{\%,t}$)	Operational cost ($H_{\%,t}$)	Clean-up cost ($J_{\%,t}$)	Extraction ($L_{\%,t}$)
1	7 %			
2	16 %			
3	16 %			
4	16 %			
5	13 %	3 %		3 %
6	11 %	5 %		7 %
7	7 %	6 %		10 %
8	5 %	6 %		10 %
9	4 %	6 %		10 %
10	3 %	6 %		10 %
11	2 %	6 %		8 %
12		6 %		7 %
13		6 %		6 %
14		6 %		5 %
15		6 %		5 %
16		6 %		4 %
17		6 %		4 %
18		6 %		3 %
19		5 %		3 %
20		5 %		2 %
21		5 %		2 %
22		5 %	100 %	1 %

Table 5.1 Initial development plan: Costs and extraction profile

[51] Example of investments: $\frac{1}{(1+1+0.125)} * 100\% = 47.05\%$

The table below shows how the cash flows are calculated in each year, t.

	Revenues
-	Operational costs
-	Investments
-	Clean-up costs
=	**Cash flow before-tax**
-	Tax
=	**Cash flow after-tax**

Table 5.2 Cash flow model

Revenues are determined each year by multiplying Q_o and Q_g with the extraction rate from the development plan (Table 5.1), together with the oil and gas prices. The prices used in the CCA and the DCF approach differ and are explained in Chapter 5.3 and 5.4. Revenues in year t, Rev_t, is expressed as:

$$Rev_t\left(P_o, P_g, C\right) = P_{o,t} Q_o L_{\%,t} + P_{g,t} Q_g L_{\%,t} \tag{5.6}$$

where $L_{\%,t}$ is the extraction rate as a percentage of the total APV of produced quantity in year t.

Operational costs (OC_t), investments (Inv_t) and clean-up costs (CUC_t) in year t are found by multiplying the total present value of costs, C, by the constants 47.05 percent, 47.05 percent and 5.9 percent, respectively, and then multiplying this answer by the ratio from the development plan (Table 5.1), shown in the formulas below.

$$OC_t(C) = 0.4705C * F_{\%,t} \tag{5.7}$$

$$Inv_t(C) = 0.4705C * H_{\%,t} \tag{5.8}$$

$$CUC_t(C) = 0.059C * J_{\%,t} \tag{5.9}$$

where $F_{\%,t}$, $H_{\%,t}$ and $J_{\%,t}$ are the weight of the APV of operational costs, investments and clean-up costs in year t, respectively. These factors are found in the development plan, Table 5.1.

Without tax, the profit function, π_t, in year t is expressed as:

$$\pi_t(P_o, P_g, C) = Rev_t(P_o, P_g, C) - Costs_t(C) \tag{5.10}$$

where $Rev_t(P_o, P_g, C)$ is the revenue in year t given by Equation 5.6. The costs in year t are equal to the sum of operational costs, investments and clean-up costs in year t, given by Equations 5.7 to Equation 5.9.

Implementation of Tax

If taxes, Tax_t, are implemented, company profit is expressed as:

$$\pi_t(P_o, P_g, C) = Rev_t(P_o, P_g, C) - Costs_t(C) - Tax_t(P_o, P_g, C) \tag{5.11}$$

In a Brown cash flow scheme, the process of finding the profit after-tax is straight forward. Taxes in year t is found by:

$$Tax_t(P_o, P_g, C) = \tau_{Brown}\left(Rev_t(P_o, P_g, C) - Costs_t(C)\right) \tag{5.12}$$

where τ_{Brown} is the tax rate in the Brown tax regime. The payable tax in the PTA is found by the following table[52]:

	Revenues
-	Operational cost
-	Depreciation
-	Clean-up cost
-	Deductible financial cost
=	Tax base of operations
-	Loss carry forward
=	**Regular tax base**
-	Uplift
=	**Special tax base**

Table 5.3 Implementation of tax

$$Tax_t = RTB_t * \tau_{CIT} + STB_t * \tau_{st} \tag{5.13}$$

Taxes in year t are equal to the regular tax base, RTB_t, multiplied by the corporate income tax rate, τ_{CIT}, plus the special tax base in year t, STB_t multiplied by the special tax rate, τ_{ST}[53]. The regular tax base and the special tax base follows Table 5.3. First, an explanation of how the tax base of operations in year t, TBO_t, is found based on the tax rules of revenues, operational costs, depreciation in the tax statement, Dep_t^{Tax}, clean-up costs and deductible financial costs,

[52] For the tax rules of the GTA see Chapter 4.4.

[53] The corporate tax is 24% and special tax is 54% in the PTA 2017. In PTA 2013, the corporate tax was 28% and the special tax 50%.

DFC_t, are given. The tax base of operations is further used to find the regular tax base and special tax base. The expression of the tax base of operations is given as:

$$TBO_t = Rev_t - OC_t - Dep_t^{Tax} - CUC_t - DFC_t \tag{5.14}$$

Revenues, operational costs and clean-up costs are equal to the input from Table 5.2 and the Equations 5.6, 5.7 and 5.9, respectively. This implies that the model assumes all incomes are taxable and all operational costs and clean-up costs are deductible. Investments are linearly depreciated over six years and depreciate from the day the expense occurs. Depreciation in the tax statement in year *t* is given by:

$$Dep_t^{Tax} = \frac{1}{6}Inv_t + \frac{1}{6}Inv_{t-1} + \frac{1}{6}Inv_{t-2} + \frac{1}{6}Inv_{t-3} + \frac{1}{6}Inv_{t-4} + \frac{1}{6}Inv_{t-5} \tag{5.15}$$

The deductible financial costs are found by Equation 4.2. We assume there are no currency losses/-gains on interest-bearing debt, IBD. The deductible financial cost in year *t* is then found by:

$$DFC_t = IE_t * \frac{\frac{1}{2}TVA_t}{AIBD_t} \tag{5.16}$$

where IE_t is interest expenses in year *t*, $\frac{1}{2}TVA_t$ is 50 percent of the tax value of fixed assets in year *t* and $AIBD_t$ is the average interest-bearing debt in year *t*. Tax value of fixed assets are found by taking the tax value of fixed assets from previous year, adding investments in year *t* and subtracting taxable depreciations.

$$TVA_t = TVA_{t-1} + Inv_t - Dep_t^{Tax} \tag{5.17}$$

Interest expenses is found by multiplying interest-bearing debt in year *t-1* by the cost of debt, r_D.

$$IE_t = IBD_{t-1} * r_D \tag{5.18}$$

The interest-bearing debt in year *t* is a constant, $w_{\%}$, of the book value of fixed assets, BVA_t, in year *t*.

$$IBD_t = w_{\%} * BVA_t \tag{5.19}$$

The book value of fixed assets in year *t* is found by taking the book value of fixed assets in year *t-1*, adding the investments in year *t* and subtracting the depreciations from the financial income statement, Dep_t^{Book}.

$$BVA_t = BVA_{t-1} + INV_t - Dep_t^{Book} \tag{5.20}$$

The book value of fixed assets depreciates by the remaining lifetime of the project, meaning investments completed in year one depreciate over 21 years, while investments conducted in year two depreciates over 20 years, and so on. This is mathematically expressed as:

$$Dep_t^{Book} = \frac{BVA_{t-1}}{22 - t} \tag{5.21}$$

The average interest-bearing debt is found by the interest-bearing debt in year *t* adding the interest-bearing debt in year *t-1*, divided by two, expressed as:

$$\frac{IBD_t + IBD_{t-1}}{2} \tag{5.22}$$

The regular tax base is found by subtracting loss carry forward in year *t*, LCF_t, from the tax base of operations in year *t*, shown in Table 5.2. If the tax base of operations minus loss carry forward is lower or equal to zero, the regular tax base is zero.

$$RTB_t = \begin{cases} TBO_t - LCF_t, if\,(TBO_t - LCF_t > 0) \\ 0, if\,(TBO_t - LCF_t \leq 0) \end{cases} \tag{5.23}$$

If the regular tax base is negative, the company gets a loss carry forward deductible next year. The loss carry forward in year *t+1* is adjusted with interest, from Equation 4.1. This is given as:

$$LCF_{t+1} = \{-(TBO_t - LCF_t)\left(1 + (12\text{–}month\ Treasury\ Bill + 0.5\%)(1 - \tau_{CIT})\right), if\,(TBO_t - LCF_t < 0) \tag{5.24}$$

If the tax base from operations is higher or equal to the loss carry forward, loss carry forward is zero.

$$LCF_{t+1} = \{0\,, if\,(TBO_t - LCF_t \geq 0) \tag{5.25}$$

The special tax base is found by subtracting the potential uplift, *U*, from the regular tax base. If the uplift is higher than the regular tax base, the special tax base is zero.

$$STB_t = \begin{cases} RTB_t - U_t, if (RTB_t - U_t > 0) \\ 0, if (RTB_t - U_t \leq 0) \end{cases} \tag{5.26}$$

If the company does not make use of all potential uplift, the company has an unutilised uplift in year *t*, UU_t.

$$UU_t = \begin{cases} U_t - RTB_t, if (RTB_t - U_t < 0) \\ 0, if (RTB_t - U_t \geq 0) \end{cases} \tag{5.27}$$

Unutilised uplift from year *t* is carried forward by Equation 4.1. This implies that the nominal value of uplift carry forward, *UCF*, in year *t+1* is expressed as:

$$UCF_{t+1} = UU_t\big(1 + (12\text{–}month\ Treasury\ Bill + 0.5\%)(1 - \tau_{CIT})\big) \tag{5.28}$$

Potential uplift in year *t*, U_t, consists of uplift from investments in year *t*, U_t^{Inv}, and the adjusted value of uplift carry forward from previous year, UCF_t. Expressed as:

$$U_t = UCF_t + U_t^{Inv} \tag{5.29}$$

Tax deductions from uplift follow the tax rules in the PTA, where companies can deduct a percentage of investment, equally over four years[54]. This annual percent is $V_{\%}$ in Equation 5.30.

$$U_t^{Inv} = V_{\%} * Inv_t + V_{\%} * Inv_{t-1} + V_{\%} * Inv_{t-2} + V_{\%} * Inv_{t-3} \tag{5.30}$$

Additionally, the Norwegian government refunds potential loss carry forward and the uplift carry forward in year 22 when the company terminates its NCS activities. Loss carry forward in year 22 is adjusted for loss in year 22 before the refund. The cash flows in year 22 are expressed as:

$$\pi_{22} = Rev_{22} - Costs_{22} - Tax_{22} + LCF_{22} + U_{22} \tag{5.31}$$

[54] 30% (7.5% yearly) in 2013 and 21.6% (5.4% yearly) in 2017.

The NPV of the profit is then found by:

$$NPV\ \pi_0\left(P_o, P_g, C\right) = NPV \sum_{t=0}^{22} \left(Rev_t\left(P_o, P_g, C\right) - Costs_t(C) - Tax_t\left(P_o, P_g, C\right)\right) + NPV\left(LCF_{22}\left(P_o, P_g, C\right) + U_{22}\left(P_o, P_g, C\right)\right) \tag{5.32}$$

Companies are expected to maximise profit by setting the first order derivative of Equation 5.32 with respect to *C* equal to zero. How the NPV of cash flows are found in the CCA and the DCF approach are described in sub-chapter 5.3 and 5.4.

Assumptions and Simplifications in the Model

The model applies a steady-state interest rate, which does not change with the business cycle. As described in Chapter 2.1, the tax system is only neutral for one specific cost of capital. The risk-free interest rate affects the cost of capital from the CAPM. For example, during a recession the interest rate is expected to drop, leading to a lower cost of capital. This implies that the tax system is too generous, resulting in incentives to overinvest. Vice versa if the economy is in an economic expansion with a high interest rate. It is difficult to design a tax system that is neutral under both an economic recession and economic expansion. Therefore, we expect that the PTA is designed to reflect neutrality in a situation with a steady business cycle with a constant interest rate.

All cash flows are received at the end of each year. Normally there is a tax credit considering payable taxes, which is neglected. A constant net interest-bearing debt to fixed asset ratio is set to 40 percent, $w_{\%}$, and reflects the average finance structure of large and medium size petroleum companies operating at the NCS (SNF, 2014). This implicitly assumes that the firm adjusts its equity by paying dividends or issuing more equity at the end of each year and debt to be risk-free. Therefore, the interest rate of debt is the risk-free ten-year Norwegian Government Bond, $r=r_D$.

Damodaran (2008, pp. 6-7) argues that the risk-free interest rate should be equal to a zero-coupon bond, where time to maturity is the expected lifetime of the project. The ten-year Norwegian Government Bond is used as the best proxy of a risk-free asset, *r*, and the rate is set to four percent. The four percent interest rate is higher than the current ten-year Norwegian

Government Bond of approximately 1.5 percent but lower than the historical average of 6.4 percent (Norges Bank, 2017). When adjusting tax allowances with interest, the twelve-month Norwegian Treasury Bill is used and is set to 3.5 percent. The ten-year Norwegian Government Bond is 0.5 percent higher than the twelve-month Norwegian Treasury Bill and captures the risk of holding long bonds [55]. For simplicity, the risk-free continuously compounded interest rate in the CCA is equal to the risk-free nominal interest rate in the DCF approach.

Exploration costs are assumed to be sunk costs and are therefore neglected. The timing of investments and the shape of production profile remain fixed in prior. The company has no opportunity to affect the initial development plan after decision time zero.

A typical petroleum field produces oil, natural gas, natural gas liquids and condensate. Oil and natural gas prices are the only prices included in the model and accounted for approximately 95 percent of the total petroleum value exported from Norway in 2016 (SSB, 2017). It is possible to implement natural gas liquids and condensate prices, but for our purpose, it would only complicate the model and give minor increased insight.

The oil price is set to 60 USD per barrel, $P_{0,o}$, while the gas price is set to 3.5 USD per MMBtu, $P_{0,g}$. This is higher than today's prices but lower than the prices in previous years. Sensitivity analyses are conducted to examine how different petroleum prices affect the results since it is not possible to find the correct normalised prices for a period of 22 years.

Lund (1987, pp. 60-61) estimates net convenience yield, δ, of oil to be four percent. In 1987, the forward market was less liquid than today, which made the estimate uncertain. Carmona and Ludkovski (2003) find the net convenience yield for oil to be volatile, but the average was around four to five percent during the period 1994 to 2003. The net convenience yield of gas has historically been even more volatile. Chiou Wei and Zhu (2006) estimate the constant net convenience yield of gas to be around three to four percent. For simplicity, net convenience yield is assumed to be four percent for both oil and gas.

[55] The premium of holding long bonds is explained by the liquidity preference hypothesis. Investors require a risk premium of holding long bonds, since there is a risk that inflation can be higher than the risk-free interest rate. See Keynes (1936) Chapter 13.

5.3 The Contingent Claims Analysis

The CCA is based on CE prices, making revenues risk-neutral[56]. In this method, all systematic risk is expected to be captured by the volatility of the underlying assets. From a government perspective costs and quantity are assumed to be non-stochastic and risk-free. Tax allowances are certain since the government refunds potential loss carry forward and uplift if the company terminates. Additionally, costs often increase when the oil price is high and are reduced when the oil price is low[57]. This mechanism implies that there is a low, maybe even negative, systematic risk of costs. For simplicity, costs are considered as risk-free. This assumption is relatively in line with the findings of Summers (1987), but in contradiction to the argumentation of Emhjellen and Osmundsen (2009). By investing in several petroleum fields, the risk of getting higher or a lower quantity than expected is diversified and is therefore unsystematic.

Price Simulations

Monte Carlo simulation is used for simulating the oil and gas prices based on a geometric Brownian motion (GBM) method. The simulations of the cost levels are made with a grid size of $500 million, within the range of $500 million to $12,000 million. Each simulation consists of at least 100,000 runs through the sequence of 22 years with stochastic prices. Between the range $7,000 million and $12,000 million, some cost levels are simulated 200,000 to 400,000 times, in order to achieve significant answers.

It is reasonable that commodities are mean reverting from a microeconomic perspective. If petroleum prices are high, producers invest more, which leads to increased supply and lower prices, and vice versa for low prices. There is evidence that the oil price is mean reverting. Pindyck and Rubinfeld (1991) apply a Dickey-Fuller unit root test and reject the random walk hypothesis for long time series of oil prices, while Pilpovic (1998) uses econometric tests to show that oil prices are mean reverting.

Still, the GBM method is preferred over the more realistic geometric mean reversion, due to less complexity and better tractability. Using this approach, the probability of longer periods with unnormal high or low prices is overrated. However, this has a minor impact on the results.

[56] CE prices and risk-neutrality are explained in Chapter 2.3.
[57] High capital expenditures make pressure on salaries and prices in the petroleum service industry.

Metcalf and Hasset (1995) find that the cumulative investment is in general unaffected by using either a geometric mean reversion or a GBM.

The formula for a GBM method are expressed as follows (Hull, 2009, p. 263):

$$dP = \alpha P dt + \sigma P dz \tag{5.33}$$

where *dP* is the simulated price in period *t*, α the expected continuously growth rate and σ the expected volatility. *dz* is the standard Wiener increment, where $dz=\epsilon\sqrt{t}$. ϵ is a random drawing number from the standard normal distribution, N(0,1). The first term of the right-hand side of the equation is the risk-adjusted price, while the second term is the volatility part which make the prices differ from the expected risk-adjusted price[58]. The price is log-normal distributed, while the return of investing in oil or gas is normal distributed (Blake & Roberts, 2006).

The derivation from Hull (2009, p. 428) is applied to simulate the future risk-adjusted oil and gas prices for each year using a GBM method.

$$P_t^{CCA} = P_{t-1}^{CCA} e^{\left(r-\delta-\frac{\sigma^2}{2}\right)T-\sigma\epsilon\sqrt{T}} \tag{5.34}$$

P_{t-1}^{CCA} is the risk-adjusted price in the previous year, *r* is the continuously compounded risk-free interest rate, δ is the marginal net convenience yield from storage, σ the volatility of the underlying asset and ϵ is a random drawing number from the standard normal distribution.

Equation 5.34 is related to the Equation 2.11. Equation 2.11 is used to find the present value of price in year *t-1*, in contradiction to Equation 5.34 that finds the expected risk-neutral price in year *t*. Therefore, the price in the previous year, P_{t-1}^{CCA}, is adjusted by the risk-free interest rate in the numerator instead of discounted in the denominator. The price in year *t-1* is discounted by the net convenience yield. The reason is that the net convenience yield is the benefit of holding the underlying asset. After one year, the owner of a forward contract receives the asset and there is no benefit of holding the asset anymore. Consequently, the price in year *t-1* is discounted by the convenience yield to find the price in year *t*.

The $\frac{\sigma^2}{2}$ part is the risk element of the first term of Equation 5.34. The risk-adjustment is the same as $\lambda\sigma_{C_1}$ term in Equation 2.11 and ensures that the prices can be treated as risk-neutral prices. The last term of Equation 5.32, $\sigma\epsilon\sqrt{T}$, is the stochastic component that make the prices

[58] This term is often called the stochastic or noise component of price.

differ from the risk-adjusted prices. By simulating the prices numerous times, this term captures the nonlinear cash flows in the PTA, caused by the asymmetric treatment of loss offset.

Oil and gas are substitutes and correlate with one another. It is necessary to adjust for the correlation when simulating the risk-neutral prices. The oil price is simulated by a random drawing number from the normal distribution, while the gas price adjusts for correlation by equation 5.35 (Hull, 2009, p. 430).

$$Z = \rho X + \sqrt{1-\rho^2} * Y \tag{5.35}$$

where X is a random drawing number from the standard normal distribution used when simulating the oil price, and Y a new random drawing number from the standard normal distribution. ρ is the correlation between oil and gas, which makes Z a correlated number from the standard normal distribution. Z is ϵ in the price function (Equation 5.34) for gas.

NPV in the CCA

In the CCA, uplift carry forward, loss carry forward, the tax value of assets and the book value of fixed assets are discounted by the risk-free interest rate, the ten-year Norwegian Government Bond. Thus, the time value of money of tax allowances and future financial tax deductions are captured. This implies that Equations 5.15, 5.17, 5.20, 5.24, 5.28 and 5.30 should be discounted by the risk-free interest rate, raised by the year. For example, in Equation 5.15 Inv_{t-5} is discounted by $(1+r)^5$.

By inserting Equation 5.6 into Equation 5.32, the oil and gas prices are the risk-adjusted prices in year zero. Costs are, as described in Chapter 5.2, the APV of costs in year zero. Thus, the present value of profit for one simulation, *i*, is simply:

$$\begin{aligned} NPV_i\, \pi_0(P_o, P_g, C) \\ = \sum_{t=0}^{22} \Big(Rev_t^{CCA}(P_o, P_g, C) - Costs_t(C) \\ - Tax_t(P_o, P_g, C) \Big) \\ + \Big(LCF_{22}(P_o, P_g, C) + U_{22}(P_o, P_g, C) \Big) \end{aligned} \tag{5.36}$$

where Rev_t^{CCA} is the risk-adjusted revenue, found by the simulated prices, from Equation 5.34.

The NPV of each development plan is the average of all simulations.

$$NPV\ \pi_0 = \sum_{i=1}^{n} \frac{NPV_i\ \pi_0\left(P_o, P_g, C\right)}{n} \tag{5.37}$$

where n is the number of simulations i.

Assumptions about Price Simulations

The historical oil and gas volatilities are found on monthly observations, during the period 1987 to 2017 for oil and 1998 to 2017 for gas. The volatility is 35 and 45 percent per year, respectively (EIA, 2017a, 2017b). The correlation between oil and gas is found to be 25 percent and based on monthly observations in the North-American market during the period 1998 to 2017, which is the most liquid market of natural gas. There is no guarantee that neither historical volatility nor historical correlation are good measurements of future volatility or correlation. A sensitivity analysis is conducted to see how changes in these variables affect the primary results.

5.4 The Discounted Cash Flow Approach

Most of the input variables in the DCF analysis is the same as in the CCA, which is essential for making a comparison of the results from the two approaches possible. Since the DCF method adjusts for risk in the denominator, not in the nominator as the CCA, some adjustments are required. First, nominal spot prices are applied, not risk-adjusted simulated prices. The nominal spot prices in year t are assumed to be equal to the forward prices in year t. Second, the sales volume is nominal, which is adjusted by the net convenience yield of four percent, both for oil and gas.

$$q_t = Q * L_{\%,t} * (1 + 0.04)^t \tag{5.38}$$

Third, the cost, C, is adjusted by the risk-free interest rate, which Lund (1992) sets to three percent.

$$C_t = C_0 * (1 + 0.03)^t \tag{5.39}$$

where C_t, is the cost in year *t* and C_0 is equal to *C* from the production function. Inserting C_t into Equations 5.7 to 5.9, investments, operational costs and clean-up costs are found for year *t*.

In the DCF approach, tax allowances are not separately discounted, and all cash flows after-tax are discounted by the cost of capital. The NPV of cash flows after-tax is found by discounting the cash flows by inserting Equation 5.32, into Equation 2.9:

$$NPV\ \pi_0 = \sum_{t=0}^{22} \frac{Rev_t - Costs_t - Tax_t}{(1+k)^t} + \frac{LCF_{22} + U_{22}}{(1+k)^{22}} \tag{5.40}$$

Assumptions in the DCF

Damodaran (2017) finds the unleveraged beta adjusted for cash to be one for petroleum companies, and PwC (2016, p. 8) finds the average market risk premium in Norway to be five percent. Based on these findings and the risk-free interest rate of four percent, a nominal cost of capital, *k*, of nine percent after-tax is applied. The cost of capital is one of the most important drivers for the NPV of a project but is uncertain. Therefore, sensitivity analyses are conducted to see how different cost of capitals affect investment distortions.

5.5 Summary of Assumptions

Summary of Assumptions in the Model	
10- year Norwegian Government Bond, *r*	4%
12-month Norwegian Treasury Bill	3.5%
Normalised oil price, p_o	60,000 USD per 1,000 barrel
Normalised natural gas price, p_g	3,500 USD per 1,000 MMBtu
Correlation between oil and gas, ρ	25%
Volatility oil, σ_o	35%
Volatility gas, σ_g	45%
Net convenience yield for oil and gas, δ	4%
Allocation of total petroleum	40% oil, 60% gas
Beta, β	1
Risk premium	5%
Cost of capital, *k*	9%
Interest-bearing debt to fixed asset ratio	40%

Table 5.4: Summary of assumptions

6. Results

This chapter presents the results of the CCA and the DCF method. The results are analysed in light of Sandmo's (1989, p. 310) definition of neutrality. Both methods present the results of a firm outside tax position before the results of a company in tax position are given. Sensitivity analyses are conducted and interpreted to ensure the validity of the results. Furthermore, the CCA and the DCF results are compared, and possible reasons for deviations are discussed. Finally, some supplementary analyses from an industrial perspective are presented.

The socioeconomically optimal profit before-tax is found by maximising the profit function (Equation 5.32). Companies choose the scale of development that maximises NPV of cash flows after-tax, which may differ from the socioeconomic optimal development plan due to taxes. Companies can have incentives to reduce the scale of development after the reduction of uplift because lower tax deductions reduce expected NPV of cash flows after-tax. The reduced tax deductions in the PTA 2017 ensure that a more significant part of the expected NPV of profit before-tax is allocated to the authorities through taxes.

This chapter analyses the welfare differences of the possible changes in the profit after-tax and tax income. Welfare differences are found by subtracting the welfare in the Brown tax from the welfare in the tax code analysed[59]:

$$W^{Tax\ code} - W^{Brown} = T^{Tax\ code} - T^{Brown} + \gamma(\pi^{Tax\ code} - \pi^{Brown}) \qquad (6.1)$$

where taxes, T, and company profit, are found from the optimal company behaviour under uncertainty. The tax code is either the PTA or the GTA. Welfare differences are determined by applying Equation 6.1 and compare the difference in tax revenue plus company profit in the tax code against tax income and company profit under a Brown tax with a tax rate of 78 percent. The analysis is first conducted for the PTA and thereafter for the GTA. It is then possible to compare the welfare differences between the two tax codes.

We have chosen to analyse Equation 6.1 in two extreme views, where gamma, γ, is either zero or one. This make it possible to find the preferable tax system under the two different social welfare preferences. A gamma of one means that tax revenue to the government and profit after-tax to the company count equally in the welfare function. In an opposite situation, where

[59] See Chapter 2.5 and Equation 2.13.

gamma is zero, only tax revenue counts. For some of the results it is clear which of the tax systems that have the highest welfare, but for some of the other results the welfare depend on the redistribution preferences. We then find the gamma that make the society indifferent between the tax regimes.

The main reason for distortions in the PTA is a combination of depreciation, uplift and financial tax deductions. This is captured by the CCA and the DCF approach. If the combination of deductions is too high, overinvestments occur, and if the combination is too low, underinvestments occur. Asymmetrical treatment of profit and loss leads to nonlinear cash flows and gives incentives to underinvest. The nonlinear cash flows are only captured by the CCA. Companies may employ a cost of capital higher or lower than what the society consider as the systematic risk, which may cause investment distortions in the DCF approach[60].

It is important to emphasise that the results are only indications of over- or underinvestments, and the sizes of the welfare differences are imprecise. A table of profit and welfare loss for all different scales of development is found in Appendix 10.3.

6.1 Contingent Claims Analysis: A Governmental Perspective

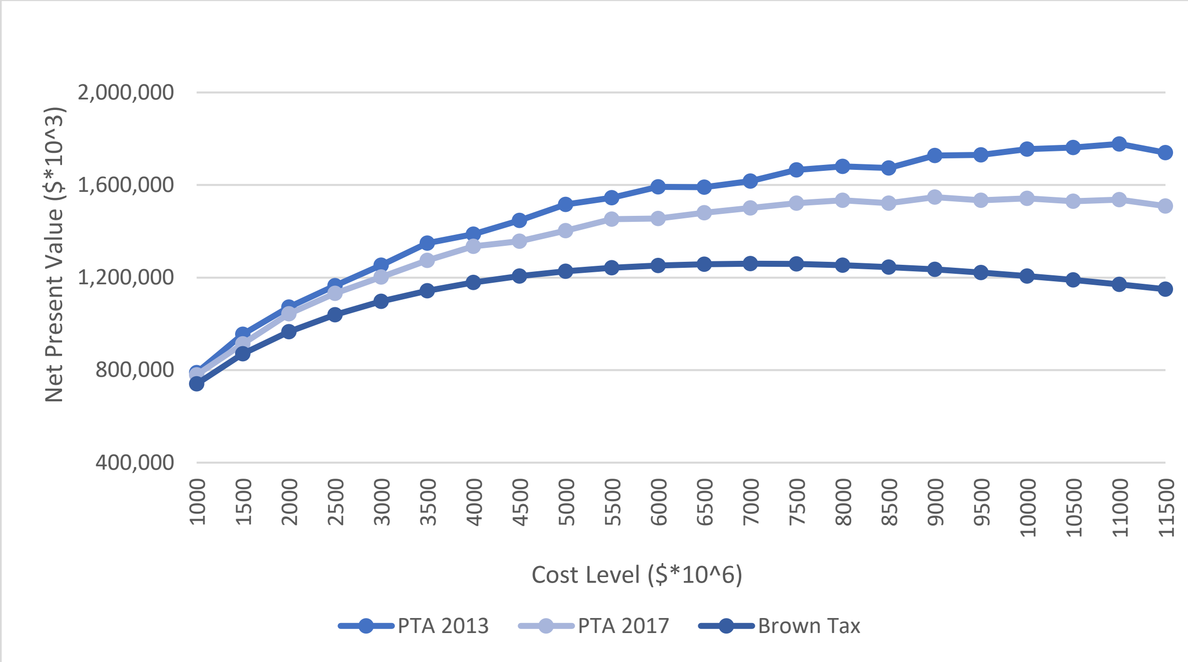
6.1.1 Outside Tax Position

A company outside tax position is expected to invest in their first petroleum field at the NCS and is outside tax position in year one.

Scale of Development Analysis

The graph below shows the NPV of cash flows after-tax for a company outside tax position for each development plan. The comparison of the PTA against the GTA is dropped since the low marginal tax rate in the GTA makes the NPV after-tax higher and a comparison difficult.

[60] Companies may use a uniform cost of capital that does not adjust for the certainty of the tax allowances and is found from the CAPM, where beta is observed in the market. See Lund (2013, 2014).



Graph 6.1 Profit after-tax with a CCA for a company outside tax position

The peaks of the NPV of profit after-tax should be at the same investment level in the PTA compared to the Brown tax to be neutral. Graph 6.1 shows that the NPV after-tax in the PTA 2013 and the PTA 2017 are above the Brown tax for all scales of development, but the PTA 2017 is closer to the Brown tax. This implies that the PTA 2017 is less distorted, meaning that profit after-tax is lower and tax income is higher for all possible scales of development after the uplift reduction.

Table 6.1 illustrates how a firm adapts under the different tax regimes, where we assume a company chooses the scale of development that maximises NPV of cash flows after-tax.

	PTA 2013	**PTA 2017**	**Brown tax**	**GTA**
1. Optimal scale of cost	11 000’	9 000’	7 000’	5 500’
2. Profit before-tax (profit function)	5 319’	5 614’	5 727’	5 646’
3. Tax revenue (simulated)	3 578’	4 064’	4 467’	1 685’
4. Confidence interval tax revenue (95%)	[3501’,3655’]	[4000’,4128’]	0	[1663’,1692’]
5. Profit after-tax (Simulated)	1 741’	1 550’	1 260’	3 961’

Table 6.1 Optimal development plans for a company outside tax position

The optimal scale of development (1) is the peak of graph 6.1. The profit before-tax (2) is found by setting the scale of development into the profit function (Equation 5.3) and is, therefore, a certain number. The distribution of profit before-tax, between tax revenue to the government (3) and profit after-tax (5), is uncertain since the results are based on simulations. Therefore, a 95 percent confidence interval of tax revenue (4) is constructed.

The optimal scale of development in the GTA is $5,500 million, and $7,000 million in the Brown tax. The GTA is distorted compared to the Brown tax for two reasons. First, the cost of equity is not deductible. Second, loss carry forward are carried forward without interest and not refunded if the company terminates. Table 6.1 shows that the optimal scale of development is $11,000 million and $9,000 million for the PTA 2013 and the PTA 2017, respectively. Hence, if companies outside tax position apply a CCA, they have incentives to overinvest compared to the GTA and the Brown tax. The incentives to overinvest are reduced after the tightening of the PTA in 2013. The driving force of these incentives to overinvest is too favourable tax allowances. The NPV of tax deductions is higher than what the company consider as investment costs since tax allowances are risk-free in the CCA[61]. The beneficial tax allowances have more impact than the disincentives to not invest due to the asymmetric loss offset.

Welfare Analysis

Benchmark Brown cash flow tax	PTA 2013	PTA 2017	GTA
Welfare difference – γ = 1	-408’	-113’	-75’
Welfare difference – γ = 0	-889’	-403’	-2,782’
Welfare difference – γ = 0 (Sensitivity analysis)	[-966’,-812’]	[-467’,-339’]	[-2804’,-2775’]

Table 6.2 Welfare analysis for a company outside tax position

The welfare analysis in Table 6.2 shows how the welfare differences differ between a gamma of one and zero. The welfare difference, when the gamma is one, is found by subtracting profit before-tax (2), from Table 6.1, from the development plan that maximises profit[62]. The welfare differences where profit after-tax and tax income to the government count equally in the social welfare function is reduced from -$408 million to -$113 million after the reduction of uplift. Companies have incentives to choose a scale of development closer to the socioeconomic optimal scale of development, reducing the welfare differences. The PTA 2017 has a higher welfare loss compared to the GTA, but are highly reduced after the uplift reduction.

The welfare differences, when tax income is the only factor in the social welfare function, is found by subtracting the tax revenue (3) from Table 6.1 from the tax income of the Brown tax.

[61] From example in Chapter 2.2.1, tax deductions, *s*, are higher than what company consider as taxable profit, *t*.
[62] The socioeconomic optimal development plan is $5,727 million. See Chapter 5.2 for further explanation.

Table 6.2 shows that the welfare differences are reduced from -$889 million in the PTA 2013 to -$403 million in the PTA 2017. The sensitivity analysis of tax income is found by subtracting the confidence interval (4) in Table 6.1 from the tax income of the Brown tax. The confidence intervals of tax revenue are not overlapping. This implies that we can be certain that tax revenue to the government has increased after the reduction of uplift. The welfare has increased for two reasons. Firstly, companies have incentives to choose a scale of development closer to the socioeconomic optimal development plan, increasing NPV of profit before-tax. Secondly, a reduced uplift increases the allocation of profit before-tax to the government.

The comparison between the PTA and the GTA are conducted with an analysis of gamma.

$$T^{PTA} + \pi^{PTA}\gamma = T^{GTA} + \pi^{GTA}\gamma \tag{6.2}$$

The gamma that ensures the same welfare in the GTA compared to the PTA 2013 and the PTA 2017 are 0.85[63] and 0.99, respectively. This implies that the welfare compared to the GTA has increased regardless of welfare preferences. Unless, the society have no redistribution preferences, $\gamma = 1$, the PTA 2017 leads to higher welfare after the reduction of uplift, compared to the GTA. As described in Chapter 4.1, the purpose of the PTA is to secure that the petroleum resources benefit the entire Norwegian population. If the society only care about minimising the distortions, the optimal solution should be to not levy any taxes at all. The government has designed the PTA with a high marginal tax rate, indicating that the society has strong redistribution preferences related to the profit before-tax. Hence, the PTA 2017 gives higher welfare than the GTA. If companies apply a CCA, where tax allowances are considered risk-free, the welfare has increased after the reduction of uplift.

6.1.2 In Tax Position

Three fields are implemented in the model for analysing a company in tax position. The model assumes that the firm started investing at the NCS nine years ago and expanded with a second field five years later. This implies that the company is in tax position when the company starts investing in field three.

The three fields are equal, with the same development plan, only start-up and termination of the fields differ. The two first fields apply historical prices for the period 2007-2016

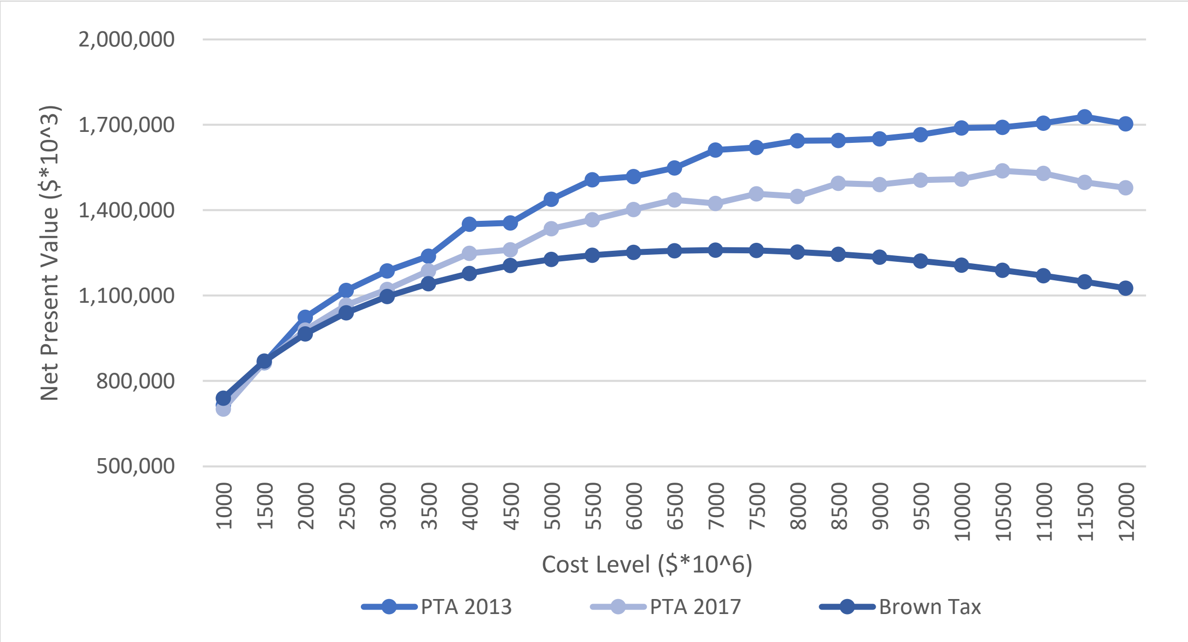
[63] See Table 6.1: $3578 + 1741\gamma = 1685 + 3961\gamma$

(EIA2017a), where there is no price uncertainty, until year zero. After year zero[64], Monte Carlo simulated prices are applied[65]. The company then chooses the scale of development that maximises NPV of profit after-tax for field three, which is the field analysed.

Field three is separated from the two first fields, making it possible to compare the results for a company in tax position against a firm outside tax position. We assume field one and two are optimally developed, with a socioeconomically optimal NPV of costs of $7,000 million. It is then possible to find the preferred scale of development of field three by deducting the NPV from field one and two.

Scale of Development Analysis

Graph 6.2 shows the NPV after-tax for a company in tax position for different scales of development for the tax systems, except the GTA. The peak values are given in Table 6.3.



Graph 6.2 Profit after-tax with a CCA for a company in tax position

Graph 6.2 illustrates that the three tax regimes have different peak levels of the optimal scale of development. The optimal scale of development is higher for the PTA 2013 and PTA 2017 compared to the Brown tax. This implies that the tax allowances are too favourable compared to the disincentives of not getting a complete loss offset.

[64] Thought as 2017.
[65] Described in Chapter 5.3.1.

	PTA 2013	PTA 2017	Brown tax	GTA
1. Optimal scale of cost	11 500’	10 500’	7 000’	6 000’
2. Profit before-tax (profit function)	5 223’	5 407’	5 727’	5 692’
3. Tax revenue (simulated)	3 529’	4 082’	4 467’	1 764’
4. Confidence interval tax revenue	[3407’,3652’]	[3984’,4281’]	0	[1741’,1789’]
5. Profit after-tax (simulated)	1 694’	1 325’	1 260’	3 928’

Table 6.3 Optimal development plans for a company in tax position

Table 6.3 shows that the optimal scale of development (1) is reduced from $11,500 million to $10,500 million after the reduction of uplift. The optimal scale of development is still high compared to the optimal scale of development in the Brown tax of $7,000 million and the GTA of $6,000 million. The profit after-tax in the PTA 2017 is closer to the Brown tax than the PTA 2013, implying that profit after-tax is reduced and tax income to government has increased for all possible scales of development for a company in tax position.

Welfare Analysis

Benchmark Brown cash flow tax	PTA 2013	PTA 2017	GTA
Welfare difference – γ = 1	-504’	-320’	-69’
Welfare difference – γ = 0	-938’	-385’	-2,703’
Welfare difference – γ = 0 (sensitivity analysis)	[-1060’,-815’]	[-483’,-186’]	[-2727’,-2678’]

Table 6.4 Welfare analyses for a company in tax position

Table 6.4 shows that the welfare differences in the PTA compared to the Brown tax are reduced from -$504 million in PTA 2013 to -$320 million in the PTA 2017 when profit after-tax and tax revenue count equally in the welfare function. The table also demonstrates that the welfare differences, when only tax income counts in the social welfare function, has been reduced from -$938 million to -$385 million. The same explanation of drivers of the results for a company outside tax position applies for a company in tax position.

The gamma that ensures the same welfare in the GTA compared to the PTA 2013 and the PTA 2017 are 0.79 and 0.89, respectively. If $\gamma < 0.89$ the PTA 2017 has a higher welfare than the GTA and if $\gamma > 0.89$ the PTA 2017 has the lowest welfare. We find strong redistribution preferences based on the argumentation from Chapter 6.1.1. Therefore, the PTA 2017 has higher welfare than the GTA. All analyses indicate that the total welfare has increased if a company in tax position apply a CCA.

6.1.3 Sensitivity Analyses

The sensitivity analyses examine a company outside tax position, before and after the reduction of uplift, since the standard deviation is lowest for one field. Sensitivity analyses of the CCA are time-consuming, due to the need of simulations. Only one high and one low factor scenario are conducted with 25,000 simulations for each scale of development. This makes the sensitivity analyses uncertain and difficult to conclude. Still, the sensitivity analyses give indications of how investment distortions are changed with different model inputs.

Sensitivity analyses of prices, factor *B* from the production function, the risk-free interest rate, volatility and correlation of the underlying assets are analysed. We believe these factors affect the results and give valuable insight. Sensitivity analyses of net convenience yield and debt to fixed assets ratio are not conducted, due to the timeframe.

It is possible to run scenario analyses which consider changes in more than one factor at the time. This is probably a more realistic approach. For example, during recessions the volatility has historically increased, the petroleum prices dropped and the risk-free interest rate decreased. It is not possible to point out which factors caused the difference in the result. Therefore, scenario analyses, where several factors simultaneously change, are not conducted.

Oil and Gas Prices

Both a bull and a bear scenario for the petroleum prices are applied. In the bull scenario, the normalised price for oil is 100 USD per barrel and 8 USD per MMBtu. In the bear scenario, the normalised price is 30 USD per barrel and 2 USD per MMBtu. The sensitivity analyses of prices do not show any differences in distortion effects. Overinvestments still occur if companies use a CCA.

Change in Factor *B*

B is the elasticity of the production function. This factor determines the returns to scale within the given petroleum field. A higher factor *B* increases both the field size and the effectiveness of investing. *B* is 0.4 and 0.7 in the small and large field size scenario, respectively. The results show that the changes in factor *B* correspond to the relative distortions from the primary results, both before and after the reduction of uplift.

Risk-Free Interest Rate

The risk-free interest rate affects the risk-adjusted prices, tax allowances and net financial cost. The risk-free interest rate is set to one and eight percent in the sensitivity analyses. The results show that changes in the interest rate only have a minor impact on investment distortions.

Volatility of Oil and Gas

The volatility of oil and gas is 20 percent and 60 percent in the low and high volatility scenario, respectively. The sensitivity analyses show that for both low and high volatility overinvestments occur. Lower volatility increases distortions, while higher volatility reduces distortions compared to the primary results. Lower volatility increases distortions, since lower volatility increases the risk-adjusted prices, resulting in higher incentives to invest[66]. Vice versa for higher volatility.

Correlation between Oil and Gas

The correlation of oil and gas is minus 100 and 100 percent in the sensitivity analyses. The results indicate that negative correlation leads to higher distortions. This is reasonable since the risk is reduced when oil and gas have a negative correlation. When oil price is high, the gas price is low and vice versa. This implies that income is relatively stable and the possibility of having a negative cash flow is reduced, increasing incentives to invest when the correlation is low. Similarly, a high correlation increases risk and reduce the incentives to invest, leading to less investment distortions, compared to the main results.

6.1.4 Summary of the CCA Results

If companies use a CCA with assumptions from a governmental perspective, where risk-free tax allowances are separated from cash flows with risk, the results are unambiguous. The reduction of uplift has increased social welfare both as a result of lower overinvestments compared to the socioeconomic optimal development plan and higher tax income. The results also show that if companies apply a CCA method, where governments assumptions are applied, the uplift should be further reduced to increase tax income and ensure neutrality. This is in line with the conclusion of the NOU2000:18 report (2000). The beneficial tax allowances are higher than the disincentives for investing due to the asymmetrical treatment of loss offset.

[66] From Equation 5.32 the $(-\frac{\sigma^2}{2})$ term of the equation adjusts for risk, making investors risk-neutral to the prices. When volatility decreases, the risk-adjusted prices and the NPV of profit increase.

The incentives to overinvest arise because of the treatment of tax allowances. When tax allowances are carried forward with interest (Equation 4.1) and discounted by the risk-free interest rate, it is a small deviation of getting tax allowances today compared to receiving it in later years. This implies that the NPV of depreciation and uplift are too high, resulting in incentives to overinvest.

The results indicate that the reduction of uplift has little effect on the neutrality of being in tax position compared to outside tax position. From a governmental perspective, tax allowances are risk-free, and companies are compensated with an almost complete loss offset of carry tax allowances forward. The confidence intervals of the results outside tax position compared to in tax position are overlapping. This means we cannot conclude that it is an advantage to be in- or outside tax position. Still, we believe there is a small advantage of being in tax position compared to outside tax position, since the risk-free interest rate is higher than the compensation for carrying tax allowances forward. We summarise that the PTA is relatively neutral for a firm outside tax position compared to a company in tax position, both before and after the reduction of uplift.

6.2 Discounting Cash Flow: An Industrial Perspective

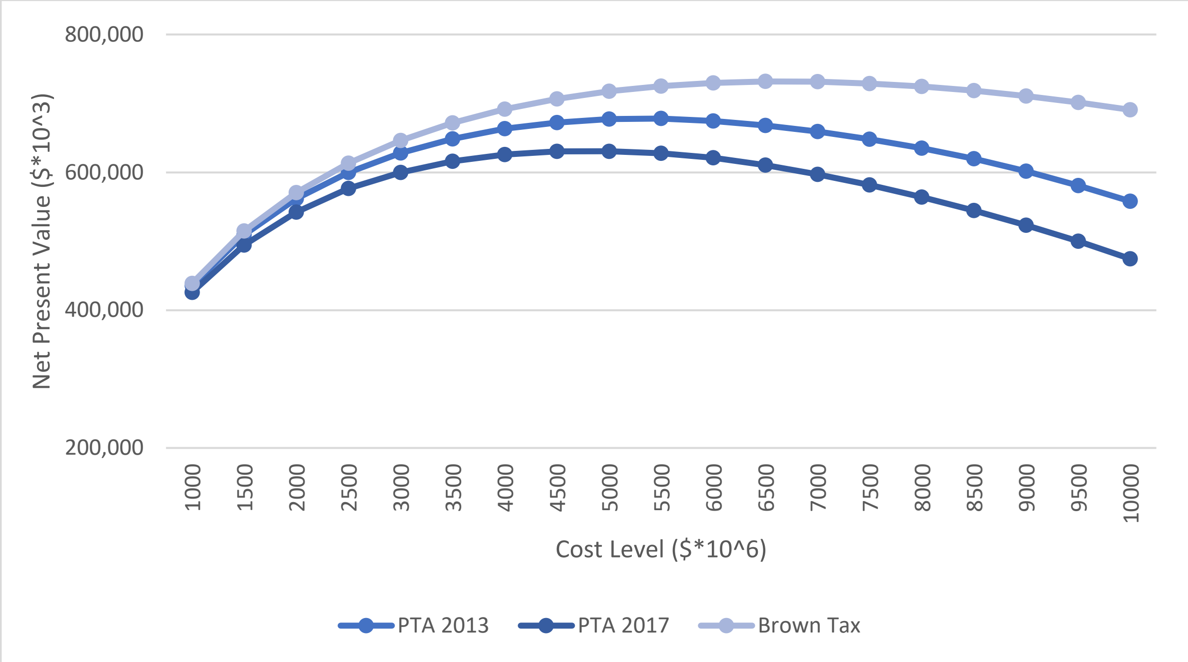
The DCF analyses are based on a nominal cost of capital of nine percent after-tax[67].

6.2.1 Outside Tax Position

Scales of Development Analysis

Graph 6.3 shows the NPV after-tax for a company outside tax position for the different scales of development plans for the tax systems, except the GTA. The peak values are shown in Table 6.5.

[67] See Chapter 5.4.



Graph 6.3 Profit after-tax with a DCF method for a company outside tax position

Graph 6.3 shows that NPV of cash flows after-tax is lower in the PTA compared to the Brown tax for all possible scales of development. The NPV after-tax in the PTA are lower since uplift and depreciation are deducted over four and six years, respectively. This reduces the NPV of tax allowances because they are discounted by the cost of capital over several years. The NPV of tax allowances is lower in the PTA compared to the Brown tax since negative cash flows in the Brown scheme are immediately refunded[68].

The optimal scale of development (1) is found by the peak of the DCF analysis in Graph 6.3. The profit before-tax (2) is given by the production function. The expected tax revenue (3) and profit after-tax (5) are found from the simulations in the CCA, not the DCF approach, due to three reasons. First, it is difficult to know the cost of capital that the government applies when discounting cash flows from tax revenues. Second, it is easier to compare the welfare differences and neutrality from an industrial perspective relative to the state's point of view by applying the same profitability measurement. Third, the welfare analyses capture the effect of the asymmetrical treatment of loss offset.

[68] From the example in Chapter 2.2.1, this implies that taxable deduction, *s*, is lower than what the company consider as taxable profit, *t*.

	PTA 2013	PTA 2017	Brown tax	GTA
1. Optimal development plan	5 500’	5 000’	6 500’	5 500’
2. Profit before-tax (profit function)	5 646’	5 577’	5 719’	5 646’
3. Tax revenue (simulated)	4 119’	4 165’	4 461’	1 685’
4. Confidence interval tax revenue	[4044’,4194’]	[4096’,4235’]	0	[1663’,1692’]
5. Profit after-tax (simulated)	1 527’	1 412’	1 258’	3 961’

Table 6.5 Optimal development plans for a company outside tax position

Table 6.5 shows that the optimal scale of development is $5,500 million for the PTA 2013, which is equal to the GTA, but lower than the Brown tax of $6,500 million. This implies that the PTA is neutral from an industrial perspective outside tax position compared to the GTA, but companies underinvest compared to the Brown tax. After the reduction of uplift, the optimal scale of development is reduced to $5,000 million. Hence, companies have incentives to underinvest compared to both the Brown tax and the GTA.

Table 6.5 also shows that the optimal scale of development with the Brown tax is lower than the maximum of the profit function (Equation 5.3) of $7,000 million. The reason is that a cost of capital of nine percent is higher than what the society and the government consider as the systematic risk[69]. This implies that underinvestment may occur in a neutral tax system[70]. There are two reasons for underinvestments in the PTA compared to the socioeconomic plan of $7,000 million. First, the cost of capital is higher than the systematic risk. Second, the NPV of tax deductions is too low to ensure neutrality.

Welfare Analysis

The welfare differences in Table 6.6 is measured against the Brown tax where the scale of development is $6,500 million, not the socioeconomically optimal development plan of $7,000 million.

[69] With a Brown tax, the socioeconomically optimal development plan is chosen if the cost of capital is eight percent.
[70] Further explained under Chapter 2.4.

Benchmark Brown cash flow tax	PTA 2013	PTA 2017	GTA
Welfare difference – γ = 1	-73’	-142’	-73’
Welfare difference – γ = 0	-342’	-296’	-2,776’
Welfare difference – γ = 0 (sensitivity analysis)	[-417’,-267’]	[-371’,-232’]	[-2798’,-2769’]

Table 6.6 Welfare analyses for a company outside position

When company profit and tax revenue counts equally in the welfare function, the welfare differences have increased from -$73 million to -$142 million after the uplift reduction. The preferred scale of development is lower compared to the socioeconomic optimal development plan, leading to a higher welfare difference.

Table 6.6 indicates that the welfare differences, when only tax income counts in the welfare function, has been reduced from -$342 million to -$296 million after the reduction of uplift. By comparing the PTA 2013 against the PTA 2017, the welfare is equal to a redistribution preference of a gamma of 0.40. This implies that if $\gamma < 0.40$ in the social welfare function the PTA 2017 has the highest welfare, and if $\gamma > 0.40$ in the social welfare function the PTA 2013 has the highest welfare. As explained under the welfare analysis in Chapter 6.1.1, the society has strong welfare preferences for redistribution, but it is not possible to know the exact gamma the society apply. The analysis is uncertain because we do not know societies’ welfare preferences for redistribution and because there are overlapping confidence intervals.

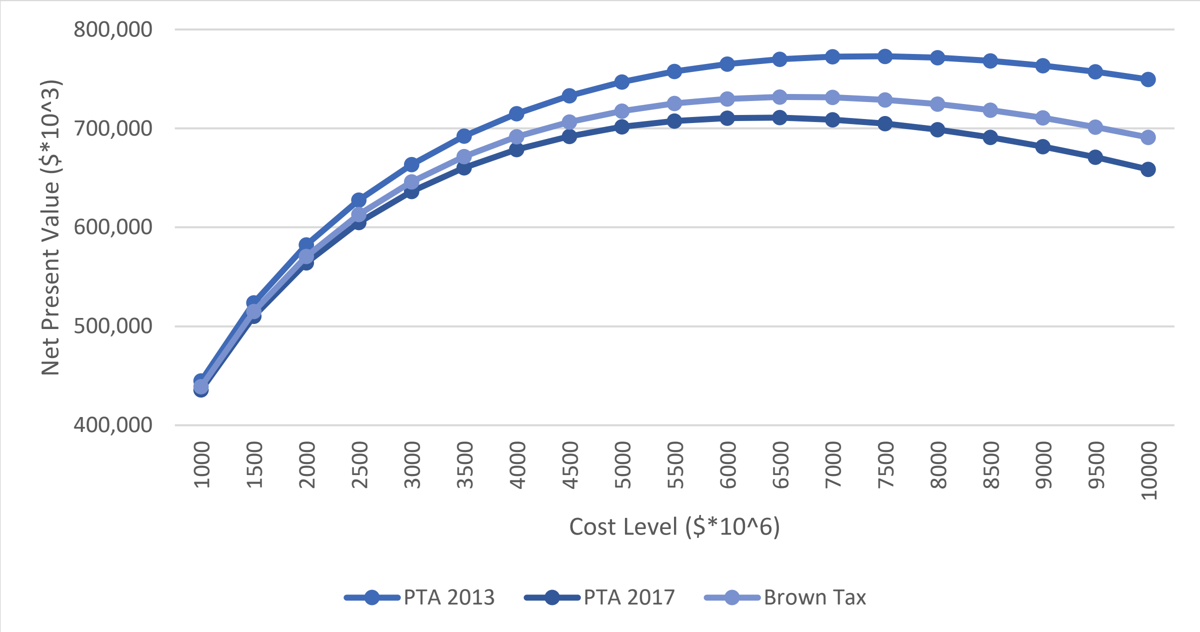
There are two conflicting effects of the welfare of the reduction of uplift. As explained above, reduced uplift leads to incentives to choose a lower scale of development, reducing expected profit before-tax and therefore the potential tax income. Lower uplift allocates more welfare from profit before-tax to the government. Thus, the tax income of each scale of development is increased, more formally shown in Graph 6.3. It is not possible to know which effect that has the strongest impact, and more simulations are required to be conclusive.

The gamma that gives the same welfare in the PTA 2013 and PTA 2017 compared to the GTA is 1.00 and 0.97, respectively. This implies that the welfare is higher in the PTA 2013 for all $\gamma < 1$ compared to the GTA, the same applies for the PTA 2017 if $\gamma < 0.97$. Since the society has strong redistribution preferences, the PTA 2013 and PTA 2017 give higher welfare than the GTA if companies outside tax position apply a DCF method.

6.2.2 In Tax Position

The DCF analysis, for a company in tax position, assumes that tax allowances are deducted in the same year as they occur. The risk of not deducting tax allowances is captured by the cost of capital, not the expected cash flows.

Scales of Development Analysis



Graph 6.4 Profit after-tax with a DCF method for a company in tax position

Graph 6.4 shows that the PTA 2013 is too favourable for a firm in tax position. The NPV of cash flows after-tax is above the Brown tax for all possible scales of development. After the reduction of uplift, the peak value of the investment level is the same as the Brown tax. This implies that the PTA 2017 is neutral. Tax income to government has increased, and company profit is reduced for all possible scales of development after the uplift reduction.

	PTA 2013	**PTA 2017**	**Brown tax**	**GTA**
1. Optimal development plan	7 500’	6 500’	6 500’	6 000’
2. Profit before-tax (profit function)	5 720’	5 719’	5 719’	5 693’
3. Tax revenue (simulated)	4 161’	4 375’	4 461’	1 765’
4. Confidence interval tax revenue	[4072’,4250’]	[4228’,4522’]	0	[1741’,1789’]
5. Profit after-tax (simulated)	1 559’	1 344’	1 258’	3 928’

Table 6.7 Optimal development plans for a company in tax position

Table 6.7 shows that the optimal scale of development is reduced from $7,500 million to $6,500 million after the reduction of uplift in 2013. The PTA 2017 is neutral to the Brown tax of $6,500 million, but slightly above the GTA of $6,000 million. The tax system is relatively neutral from an industrial perspective after the reduction of uplift compared to both benchmarks.

Welfare Analysis

The welfare differences are measured against the optimal development plan in the Brown tax of $6,500 million.

Benchmark Brown cash flow tax	PTA 2013	PTA 2017	GTA
Welfare difference – $\gamma = 1$	1’	0	-26’
Welfare difference – $\gamma = 0$	-300’	-86’	-2 696’
Welfare difference – $\gamma = 0$ (sensitivity analysis)	[-389’,-211’]	[-233’,61’]	[-2720’,-2672’]

Table 6.8 Welfare analyses for a company in tax position

Table 6.8 shows that there are no welfare differences between the PTA 2013, the PTA 2017 and the Brown tax, if company profit and tax revenue count equally in the welfare function. This implies that the PTA 2017 is neutral from the industrial perspective for a company in tax position. When only tax count in the welfare function, the welfare differences in the PTA 2013 and the PTA 2017 are reduced from -$300 million to -$86 million, respectively. The allocation of profit before-tax between companies and government has changed, leading to a higher tax revenue and lower profit after-tax. Since the profit before-tax is approximately equal in the PTA 2013 and the PTA 2017, we can be certain that tax revenue has increased, even if the confidence intervals are overlapping. For all redistribute preferences, the PTA is less distorted than the GTA. The GTA is distorted since companies are not compensated for the cost of equity. The results are clear; if companies in tax position apply a DCF method, the welfare has increased after the uplift reduction.

6.2.3 Sensitivity Analyses

Oil and Gas Prices and Change in Factor *B*

The results of the sensitivity analyses of changes in petroleum prices and factor *B* only indicate some small deviations from the main results. From an industrial perspective, the primary results imply that the PTA is unfavourable for a firm outside tax position and relatively neutral for a company in tax position after the reduction of uplift.

Cost of Capital

The sensitivity analyses of cost of capital show the preferred scale of development with a cost of capital of seven and eleven percent, both for a firm outside tax position and for a company in tax position. The welfare for the different scales of development is found in Appendix 10.3.

	Outside tax position		**In tax position**	
Cost of capital	**PTA 2013**	**PTA 2017**	**PTA 2013**	**PTA 2017**
7 %	7,500’	6,500’	10,000’	8,500’
9 %	5,500’	5,000’	7,500’	6,500’
11 %	4,000’	3,500’	5,500’	4,500’

Table 6.9 Sensitivity analyses of cost of capital

Table 6.9 shows that the optimal scale of development is sensitive to the cost of capital employed. For example, the optimal scale of development for a company in tax position applying a cost of capital of seven percent is \$8,500 in the PTA 2017. If the same company applies a cost of capital of eleven percent, the optimal scale of development is \$4,500 million.

6.2.4 Summary of DCF Results

If petroleum companies outside tax position apply a DCF method, they have incentives to underinvest compared to the GTA and the Brown tax, and the disincentives have increased after the uplift reduction. This implies that the profit before-tax is reduced. The effect on tax revenue is uncertain due to the wide, overlapping confidence intervals. The effect on welfare is therefore also uncertain and depend on the redistribution preferences. For companies in tax position, the PTA are more neutral after the reduction of uplift compared to both the GTA and the Brown tax. Tax revenue has increased which implies that the welfare is higher for all redistribution preferences.

By comparing the results, there are barriers to entry at the NCS and the barriers have increased after the reduction of uplift. Depreciation and uplift are deducted the same year as they occur for a company in tax position, while companies outside tax position carry tax allowances forward until they are in tax position. The industry discounts all cash flows by the cost of capital, while tax allowances are only compensated by the risk-free interest rate adjusted by the corporate income tax (Equation 4.1). This implies that the present value of carrying tax allowances forward is reduced, and creates higher barriers to entry. From an industrial perspective, there are therefore distortions between firms outside tax position and companies in tax position.

However, the barriers to entry may be overrated in the DCF analyses. Only one large petroleum field is analysed, where extraction starts in year five. Companies outside tax position may reduce the barriers to entry by either buying a share in an already producing petroleum field or investing in a small project, where extraction starts earlier than five years after the first investment. Then, the company is liable for tax earlier, and the difference of the NPV between a firm in tax position compared to one outside tax position is reduced. We conclude that there are barriers to entry from an industrial perspective, but the indications of the results may be too high.

We point out that the results are sensitive to the cost of capital applied. The sensitivity analyses show that if the cost of capital is reduced overinvestment may occur, and in contrary, if the cost of capital increases, underinvestment can occur.

6.3 Comparison and Summary of the two Methods

The results are ambiguous. We find that the combination of depreciations, uplift and financial tax deductions are too high if companies apply a CCA, leading to a favourable PTA compared to the GTA and the Brown tax. After the reduction of uplift, the incentives to overinvest are reduced, but still too high. The findings are consistent with the conclusion in the NOU2000:18 report (2000). If companies use a DCF method, the neutrality in the PTA depends on the tax position. In tax position, the PTA is relatively neutral after the reduction of uplift, while there are disincentives to invest if the company is outside tax position.

The welfare analyses in the CCA shows that both profit before-tax and tax income have increased regardless of the tax position. This implies that welfare has increased after the uplift reduction. In the DCF analyses, the welfare effect of a firm outside tax position is uncertain, while the welfare has increased based on the investment decision for a company in tax position. All analyses demonstrate that the welfare is higher in the PTA compared to the GTA for all relevant redistribution preferences.

The reasons for the differences of the neutrality within the two different methods are mainly as a consequence of the treatment of tax allowances and the employed cost of capital. From a governmental perspective, tax allowances are risk-free and discounted by the risk-free interest rate. This is in line with the neutrality properties of Fane (1987). The industry applies a DCF method in their investment analysis, where all cash flows are discounted by the cost of capital.

The cost of capital is higher than the risk-free interest rate, leading to a reduced NPV of deducting investments through depreciation and uplift over several years. This effect is more significant for a firm outside tax position, compared to a company in tax position, since companies cannot deduct tax allowances before the profit before-tax is positive. The cost of capital in the DCF analyses is higher than the systematic risk from a society perspective. This is illustrated in Table 6.5, where companies have incentives to choose a scale of development of $6,500 million, less than the socioeconomically optimal plan of $7,000 million.

The asymmetrical treatment of profit and loss in the PTA creates disincentives for investments and is another potential reason for differences between the two approaches. As explained in Chapter 2.3, asymmetrical treatment of profit and losses lead to nonlinear cash flows and incentives to underinvest. The CCA captures these nonlinearities, while the DCF does not. The analysis shows that the tax allowances are more favourable than the disincentive to invest as a result of an incomplete loss offset.

All analyses show that the Brown tax is both more neutral and give higher tax income to the government. Based on these results, the government should examine if it is possible to implement a Brown tax instead of the PTA, without too many complications. Notwithstanding, the government should consider ensuring that a larger part of the depreciations and the investment uplift are deducted closer to the year the investment is conducted. This will reduce the differences in the optimal scale of development of using a CCA, where tax allowances are considered risk-free, compared to a DCF method for investment decisions.

It is a small deviation between the optimal scale of development in the GTA for a company that applies a CCA or a DCF method compared to the optimal scale of development in the PTA. There are essentially two reasons for this. First, the tax allowances represent a more significant part of the total cash flow in the PTA compared to the GTA due to the high marginal tax rate in the PTA. Second, unutilised tax allowances are refunded in the year the company terminates its NCS activities, making tax allowances risk-free. These results imply that, compared to companies onshore, there are more important that petroleum companies separate tax allowances from risky cash flows.

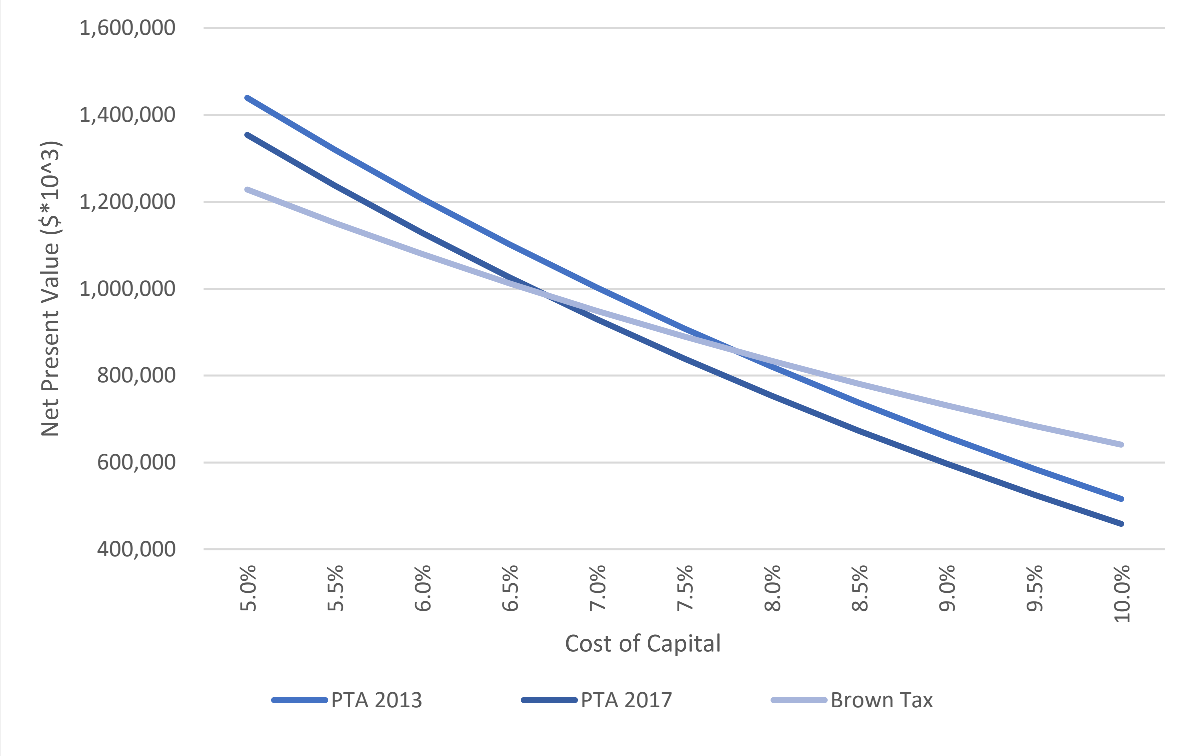
To summarise, if companies apply a CCA with the assumptions suggested by the Ministry of Finance, where tax allowances are risk-free, companies have incentives to overinvest. In contrary, if companies apply a DCF method, where all cash flows are discounted by one uniform cost of capital, found from the market, companies outside tax position have incentives to underinvest. Companies in tax position have incentives to choose the scale of development equal to the non-distorted Brown tax. Therefore, the neutrality of the tax system depends on the method applied, tax position and the cost of capital employed in the DCF analyses.

6.4 Supplementary Analyses from the Industrial Perspective

6.4.1 Sensitivity Analyses of the Cost of Capital

As described in Chapter 2.1, the tax system is only neutral for a project for one specific cost of capital, and that specific cost of capital varies between projects. The purpose of these sensitivity analyses is to find the cost of capital that ensure neutrality of PTA against the Brown tax. The GTA is left out in this analysis since the NPV of cash flows after-tax for the project is higher in the GTA, making a comparison between the PTA and the GTA complicated.

The graphs below is based on the socioeconomic optimal development plan of $7,000 million, first for a firm outside tax position then for a company in tax position. From a society perspective, the cost of capital employed by the industry is uncertain due to information asymmetry. Only insiders in a company know the exact cost of capital applied in the capital budgeting analysis of a project. We point out that the cost of capital that ensure neutrality in this analysis is only valid for the inputs in this particular model and other models with different assumptions may give other answers.

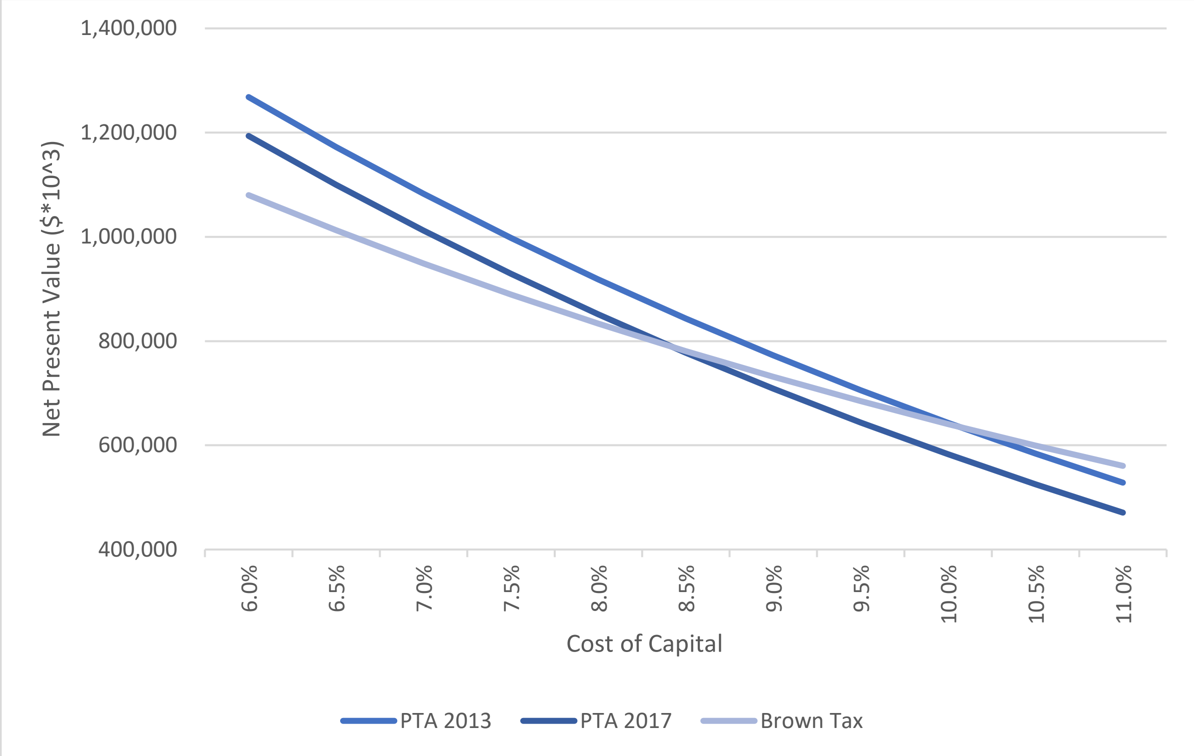


Graph 6.5 Sensitivity analysis of the cost of capital for a company outside tax position

The intersection between the NPV of cash flows after-tax in the PTA 2017 and the Brown tax is 6.7 percent. This implies that if the cost of capital is lower than 6.7 percent, the PTA 2017 is favourable compared to the Brown tax. If the cost of capital applied by the petroleum sector is higher than 6.7 percent, the PTA 2017 is unfavourable. The intersections of the PTA 2013 compared to the Brown tax is 7.8 percent with the same reasoning as above.

A cost of capital requirement of 6.7 percent is low compared to the expected cost of capital of nine percent. 6.7 percent implies a beta of a project of 0.54, close to a 50 percent reduction of the beta used in the main analyses[71]. The cost of capital seems to be too low, especially when we consider that companies often use hurdle rates in investment analyses[72]. The PTA 2013 is probably closer to the average cost of capital applied by the industry, but still a bit lower than what we expect to be the average requirement at the NCS.

[71] 4%+β*5% = 6.7%. Solving the equation, the beta is 0.54.
[72] See Graham and Harvey (2001).



Graph 6.6 Sensitivity analysis of the cost of capital for a company in tax position

The intersection of NPV of cash flows after-tax between the PTA 2017 and the Brown tax is 8.4 percent for a company in tax position. This implies that if companies use a cost of capital lower than 8.4 percent, the NPV of a project is higher with the PTA 2017 compared to the Brown tax. If the company uses a cost of capital higher than 8.4 percent, the NPV of the project is lower in the PTA 2017 compared to the Brown tax. The interception is 10.2 percent between the PTA 2013 compared to the Brown tax, with the same reasoning as above. We find a cost of capital of 8.4 percent to be close to neutral, based on the findings of a cost of capital of nine percent in Chapter 5.4. 10.2 percent is probably a bit high, implying that the PTA 2013 is favourable compared to the Brown tax.

If we compare the two results for a company outside tax position and in tax position, there are barriers to entry. The cost of capital has to be lower for a firm outside tax position to ensure neutrality compared to a company in tax position.

6.4.2 Internal Rate of Return Analyses

The purpose of the IRR analysis is to show the neutrality properties of the PTA by using a different profitability measurement than the NPV. From Sandmo's (1989, p. 310) definition, the PTA is neutral when the IRR after-tax is equal to the IRR of the benchmark. The IRR measurement has several weaknesses[73]. Still, IRR is often used for investment decisions[74]. Therefore, the method is useful for analysing potential investment distortions from an industrial perspective. We analyse the IRR when the optimal scale of development is $7,000 million. A lower scale of development gives higher IRR, while a higher scale of development gives lower IRR.

	PTA 2013	**PTA 2017**	**Brown tax**	**GTA**
Outside tax position	15%	15%	22%	19%
In tax position	18%	17%	22%	19%

Table 6.10 The IRR analyses

The results indicate that the IRR is lower for the two petroleum tax schemes compared to both the Brown tax and the GTA irrespectively of the tax position. There are small deviations between the PTA 2013 and PTA 2017. The IRR is lower than the GTA since the high marginal tax rate in the PTA reduces the NPV of the cash flow before-tax more than the compensation of tax deductions. The IRR is lower in the PTA compared to the Brown tax because investments are conducted early in the lifetime of the project with the Brown tax, while the depreciation and uplift in the PTA are deducted over several years.

It is not possible to measure the exact welfare differences using IRR analyses. However, the intuition of the results can be applied to discuss potential over- and underinvestments. The IRR from Table 6.10 is high compared to the expected cost of capital, making it unlikely that this project is rejected. In a situation where the petroleum field is only marginally profitable, the IRR may be just above the required rate of return for the Brown tax and the GTA, but below for the PTA. The company can then have incentives to either reject a marginally profitable project with a Brown tax or choose a scale of development lower than the socioeconomic optimal development plan[75].

We summarise; if companies use IRR, they have incentives to underinvest. However, the change in uplift does not indicate that the IRR has been much affected. Graham and Harvey (2001) find the NPV to be the most important tool for investment decisions. Therefore, we rely most on the NPV results from Chapter 6.1 and 6.2 but highlight that the IRR to some extent, may affect investment decisions negatively.

[73] See Brealey, Myers and Allen (2014, pp. 113-118).
[74] Graham and Harvey (2001) find that 75 percent of companies use IRR for investment decisions.
[75] The company then only extract the most profitable part of the petroleum field. Example, the IRR increases to 29 percent in the PTA in 2017 if the company in tax choose a scale of development of $1,000 million.

7. Discussion and Criticism of Model

This chapter discusses which result we emphasise the most from Chapter 6. How the materiality criteria may affect investment decisions is discussed. Finally, a criticism of the results and the model is given.

7.1 Which Results to Emphasise?

As the analyses in Chapter 6 showed, the CCA and the DCF approaches have different drives and incentives to choose the optimal scales of development. Therefore, the optimal investment level deviate between the two methods. There are also some deviations from the optimal scale of development if the company is in tax position or not. This sub-chapter first discusses which methodology we find the most important of the CCA and the DCF approach, before a discussion of tax position is given.

The CCA or the DCF approach?

The petroleum industry makes investment decisions regarding the scale of development, not the government. If companies separate tax allowances and discount them by a risk-free interest rate, the CCA results are the most important to emphasise. If companies use a DCF method where all cash flows are discounted by a uniform cost of capital, the results from the DCF approach should be emphasised the most. To conclude which results that are the most important, we discuss which method the industry applies.

Lund (2013, pp. 16-18) argues that separating cash flows are well documented in theory. Lund refers to both research and finance textbooks where the PDCF method is presented. Therefore, companies should have knowledge and competence to value tax allowances separately, as the Ministry of Finance suggests. Since the PTA is based on the neutrality properties of Boadway and Bruce (1984) and Fane (1987), the best theoretical way is to discount tax allowances separately from risky cash flows.

On the other hand, surveys reveal that companies do not in general separate tax allowances. Summers (1987, p. 299) conducts a survey of the 200 largest companies in the United States and finds that only six percent of companies separate cash flows in their capital budgeting analyses. Several of these companies did not distinguish between operating profit and depreciation allowances. Boston Consulting Group (2007) also finds that the petroleum industry applies one uniform discount rate for all cash flows.

Based on these surveys, we believe the DCF results are the most important to emphasise. Still, we cannot exclude the possibility that some petroleum companies separate tax allowances in their capital budgeting.

Tax Position

Almost all large and medium size petroleum corporations are in tax position at the NCS (SNF, 2014). This indicates that the results for a company in tax position are the most important to emphasise. Moreover, as discussed in Chapter 6.2.4, we find the barriers to entry to be overrated and the preferred scale of development for a firm outside tax position to be closer to the preferred scale of development in tax position, than what the DCF results demonstrate. Therefore, we find the DCF results for a company in tax position to be the most important.

Based on the results for a company in tax position applying a DCF method, we find it likely that the PTA is relatively neutral and tax income has increased after the uplift reduction. However, if companies use a CCA, where tax allowances are separated from the risky cash flows, these analyses do not affect the conclusion. Also, the CCA indicates that the PTA is less distorted and that tax income has increased after the uplift reduction.

7.2 Materiality

According to finance theory, projects with positive NPV are conducted. As explained in Chapter 2.4, companies may use other profitable measurements then NPV which affect investment decisions, such as materiality. If companies apply materiality in investment decisions, the optimal scale of development from the results in Chapter 6, may be overrated for small fields with low NPV.

Osmundsen et al. (2000) and Kon-Kraft (2003) argue that materiality impact how companies make investments decisions at the NCS[76]. The aim of a petroleum company is to find the combinations of projects which gives the highest possible NPV after-tax. In this way, projects

[76] NOU2000:18 (2000, pp. 20, 265-270) also discusses potential problems regarding materiality, but do not find it reasonable to change the tax system to stimulate small projects with low NPV.

with different NPV are ranged after the size of the NPV, and the projects with the highest NPV after-tax in relation to the input of scarce factors are preferred (Osmundsen et al., 2000, p. 6).

Today, the NCS is in a mature phase, where several fields may be only marginally profitable. The timing of the reduction may increase the materiality problem since the NPV of cash flows after-tax is reduced after the reduction of uplift. It is, however, difficult to know the exact impact of how materiality affects investment decisions. Therefore, we assume capital markets are rational and allocates resources to projects with positive NPV regardless of the size of the NPV in our analyses.

7.3 Criticism of the Model and Results

A weakness in our thesis is that the theoretical model field and production function are based on research by Lund (1987, 1992), when the NCS was in a less mature phase[77]. The average petroleum field size, the expected cost per petroleum quantum and the extraction efficiency at the NCS have changed during this period. The model inputs should have been updated to increase the realism. Variable A is the only variable we have been able to adjust to get an approximately equal size of the theoretical petroleum field as Lund in 1987. Therefore, the NPV of profits and the welfare differences should be interpreted as indications, not exact sizes.

Even if the model makes use of a production function, it is still static, due to the fixed development plan. In the real world, decisions are made continuously when new information is provided. A more realistic approach, based on company behaviour, would be to implement a possibility of developing a secondary or enhanced recovery operations with another production function as Smith (2014). Smith's model does not capture the potential nonlinearity in the cash flows, as a result of asymmetrical treatment of profit and loss, and is therefore not applied.

We considered the possibility of improving the model by implementing real options, where the company could decrease or increase the investment of the initial development after decision time zero, when new price information arrives. Such real options have several limitations. First, it is difficult to implement the options in the DCF analyses. This makes the

[77] Lund (1987, p.57) uses a Wood Mackenzie report from 1985 to design the development plan and the production function. It is possible to find newer versions of the Wood Mackenzie report to update the model, but it is not publicly available and expensive to achieve.

results from the DCF method and the CCA less comparable. Second, the standard deviations of the results in the CCA would significantly increase, making it difficult to conclude based on the results.

A model field, employing a production function, expects companies to select the scale of development that maximises expected NPV after-tax. This is not necessarily the case for all investment decisions. Especially for near-fields developments in mature areas, the company may only choose between investing or not investing at all. The model analyses a relatively large field and does not take into account that the investment decision of scale of development may be different for small projects.

The two different approaches also have some weaknesses. The CCA is based on simulations, which is time-consuming and making it difficult to re-test our results. In Chapter 5, we argued that costs increase with high petroleum prices and decrease with low prices, but we have not been able to prove that the costs are risk-free. It is possible that we have undervalued the systematic risk to some extent in the CCA. In the DCF analyses, the results are sensitive to the cost of capital employed. Therefore, the results should be interpreted as indications, not facts.

However, we are confident that even if the model applied is static and not updated, it is superior to a static model field. The main advantage by applying a production function is that it allows for a quantification for any given production possibilities. Hence, it is possible to measure both changes in profit before-tax, profit after-tax and tax income, and compare the welfare differences.

8. Conclusion

This thesis has examined possible investment distortions as a result of the reduction of investment uplift in the Petroleum Tax Act (PTA). The study relied on one unified model with an analytical production function, which describes how companies exploit production opportunities differently under the different tax systems. We expected companies to choose the scale of development that maximises net present value (NPV) of cash flows after-tax. If companies choose a scale of development which deviates from the socioeconomic optimal development plan, investment distortions occur. Investment distortions and welfare differences are measured against the non-distorted Brown cash flow tax and the General Tax Act (GTA).

Two different approaches were applied, a contingent claims analysis (CCA) and a discounted cash flow (DCF) method. The CCA reflected the government's point of view on neutrality, in which they separate certain tax allowances from cash flows with risk. Tax allowances were considered risk-free and in line with the neutrality properties of Boadway and Bruce (1984) and Fane (1987). All systematic risk was assumed to be found by the price volatility of the underlying assets; oil and gas. This approach also captured that the PTA treats profit and loss asymmetrically, leading to nonlinear cash flows after-tax and potential investment distortions. Research shows that in general the petroleum industry does not separate cash flows. Instead, the industry applies a DCF approach, where all cash flows are discounted by one uniform cost of capital.

If companies apply a CCA where tax allowances are considered risk-free and separated from the risky cash flows, they have incentives to overinvest, but the incentives to overinvest are reduced after the uplift reduction. Based on these results, the government may argue that tax deductions are still too high and that the uplift should be further reduced to ensure neutrality. The social welfare has increased after the reduction of uplift, as a result of lower overinvestments compared to the socioeconomic optimal development plan and a higher tax income. The PTA is relatively neutral for investment decisions with respect to the treatment of companies in different tax positions, both before and after the reduction of uplift.

If companies apply the DCF method, the results are ambiguous. The DCF analysis showed that companies outside tax position have incentives to underinvest compared to the Brown tax and the GTA. Potential investment distortions have increased after the uplift reduction, while the effect of tax revenue is uncertain. For companies in tax position, the results indicated that the PTA is relatively neutral and tax revenue has increased after the reduction of uplift. Hence, it is an advantage to be in tax position compared to outside tax position. We highlight that the results are sensitive to the cost of capital applied.

There are mainly two reasons why the results from the governmental and industrial perspective deviate. First, tax allowances are valued differently. From the state's point of view, unused tax deductions are carried forward adjusted by the interest rate after corporate income tax and discounted by the risk-free interest rate. This implies that there is a small deviation of getting tax allowances today compared to receiving it in later years. From an industrial perspective, the tax allowances are discounted by the cost of capital. This reduces the NPV of tax allowances that are due in the future such as depreciations and uplift. From an industrial perspective, the effect is even more important for companies outside tax position. Secondly, companies tend to use a cost of capital higher than the systematic risk since they may not adjust the cost of capital based on the certainty of tax allowances.

We have also discussed other possible reasons for investment distortions. Companies may use internal rate of return (IRR) and the materiality criteria in investment analyses. The IRR analyses and the materiality discussion indicated that companies may have incentives to underinvest at the NCS, but these investments decisions criteria lack empirical evidence. We do not know how these profitability measurements affect the chosen scale of development and are therefore not emphasised in the conclusion.

Summers (1987) and Boston Consulting Group (2007) find that companies, in general, apply a DCF method with one uniform cost of capital. Therefore, we found it most reasonable to emphasise the DCF results. Almost all medium and large petroleum corporations at the NCS are in tax position (SNF, 2014). Additionally, we expect that companies outside tax position can easily become tax paying by either buying a share in an already producing petroleum field or investing in a small project. Hence, we found the results for a company in tax position to be the most important.

We highlight that the results are dependent on assumptions in the model, the method applied and tax position. Based on the DCF result for a company in tax position, we conclude that the PTA is relatively neutral after the reduction of uplift. The Norwegian government has obtained the goal of increasing total welfare and tax income after the tightening of the PTA in 2013.

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10. Appendix

10.1 Glossary and Definitions

Glossary	
APV	Adjusted Present Value
CAPM	Capital Asset Pricing Model
CCA	Contingent Claims Analysis
CE	Certainty Equivalent
DCF	Discounted Cash Flow
GBM	Geometric Brownian Motion
GTA	General Tax Act
MMBtu	Million British thermal units
NCS	Norwegian Continental Shelf
NOU	Norges Offentlige Utredninger (Official Norwegian Report)
NPD	Norwegian Petroleum Directorate
NPV	Net Present Value
PDCF	Partial Discounted Cash Flow
PTA	Petroleum Tax Act
RRT	Resource Rent Tax
WACC	Weighted Average Cost of Capital

Table 10.1: Glossary

Definitions	
Contingent claims analysis:	A valuation method based on option pricing theory.
Convenience yield:	The benefit of holding the underlying assets instead of a future contract or a derivative.
Distortions:	A tax system that is non-neutral i.e. affects company behaviour.
Materiality criteria:	Projects must have a certain NPV to be conducted.
Neutrality:	The relative probability assessment of various decision options is the same before- and after-tax, irrespective of the tax position.

Resource rent:	The surplus value after all costs and the normal return have been deducted. Resource rent is related to extraction of natural recourses.
Risk-neutral:	A risk-neutral investor judge risky projects solely by their expected rates of return.
Symmetrical treatment:	Equal treatment of cost and income in the tax statement.
Tax allowances:	A sum to be deducted from gross income in the calculation of taxable income.
Tax position:	A company with positive tax base after deduction of tax allowances are in tax position.

Table 10.2 Definitions (Oxford Dictionaries)

10.2 Summary of Tax Systems

	Brown tax	**GTA**	**PTA 2013**	**PTA 2017**
Depreciation	No depreciation	14% balance declining method	Linear over six year	Linear over six year
Total uplift			30% over four years	21.6% over four years
Corporate income tax	78%	24%	28%	24%
Special tax			50%	54%
Total tax	78%	24%	78%	78%

Table 10.3 Summary of most important rules in the tax system

In addition, there are separate tax rules considering deductible financial costs on the tax statement. In the PTA, the deductible financial costs follow Equation 4.2, which implies there are no tax incentives to use debt compared to equity. In the GTA there are full tax deductions for financial cost, while interest expense cannot be deducted in the Brown cash flow tax.

10.3 Distortions in the Different Development Plans

Tax for the PTA 2013 and the PTA 2017 are based on simulations, and a 95 percent confidence interval is therefore constructed. The results are based on a company in tax position with the CCA.

Cost	**Profit Before Tax**	**Distortions**	**Tax Brown**	**Tax PTA 2013**	**Tax PTA 2017**
500	2,481	56.7%	1,935	[1900,2069]	[1989,2161]
1,000	3,364	41.3%	2,624	[2503,2691]	[2602,2788]
1,500	3,955	30.2%	3,085	[2921,3065]	[3084,3287]

2,000	4,390	23.3%	3,424	[3323,3538]	[3392,3610]
2,500	4,724	17.5%	3,685	[3526,3754]	[3611,3840]
3,000	4,986	12.9%	3,889	[3639,3872]	[3744,4229]
3,500	5,193	9.3%	4,051	[3697,3933]	[3744,4229]
4,000	5,355	6.5%	4,177	[3948,4223]	[3994,4246]
4,500	5,482	4.3%	4,276	[3849,4103]	[3956,4207]
5,000	5,577	2.6%	4,350	[4011,4279]	[4130,4299]
5,500	5,646	1.4%	4,404	[4125,4399]	[4140,4445]
6,000	5,693	0.6%	4,440	[4038,4314]	[4176,4501]
6,500	5,719	0.1%	4,461	[4012,4297]	[4338,4522]
7,000	5,727	0%	4,467	[4144,4364]	[4307,4480]
7,500	5,720	0.1%	4,461	[4072,4251]	[4180,4395]
8,000	5,697	0.5%	4,444	[4012,4227]	[4027,4329]
8,500	5,662	1.1%	4,416	[3885,4107]	[3937,4576]
9,000	5,614	2.0%	4,379	[3774,4002]	[4070,4253]
9,500	5,555	3.0%	4,333	[3698,3927]	[4020,4248]
10,000	5,486	4.2%	4,279	[3654,3884]	[4190,4501]

Table 10.4 *Distortions of the different development plans*

10.4 Conversion of Oil to Gas

Conversion of Oil to Gas	
1 Sm^3	6.29 barrels of oil
1 Sm^3 Oil	1000 Sm^3 gas
100 Barrels Oil	$15.9*10^3$ Sm^3 gas
1000 Sm^3 Gas	35.300 Btu

Table 10.5 Conversion of oil to gas (Norwegian Petroleum Directorate, 2017a)

To get a better understanding of how the sales volume of gas is found, we illustrate with an example based on a conversion of one million barrels of oil. The volume of oil is 0.1589825 Sm^6 (1/6.29). Since the volume of gas is set to be 60 percent of total volume, the volume of gas is $2.384738 *10^8$ Sm^3 ($\frac{60\%}{40\%} * 0.1590 * 10^6 * 10^3$). The calculations imply that the volume is $8.418*10^9$ (2.384738*35.3) Btu.