Evaluating North Sea petroleum fields

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This paper describes the main structure of a field evaluation model developed over the past six-year period. Its distinct features are user-oriented input and output sections, high flexibility, and usefulness for the firm as well as the tax law designer. Besides academic teaching and research, the model is presently adopted by two governmental agencies and one international oil company.

Deciding if or how to develop North Sea petroleum fields is a complex task. Restricting attention to the economic part of the problem, it has a large number of components, a long planning horizon, and significant uncertainty in virtually every component. This is typical on several aggregation levels; from the individual oil firm facing investment decisions to the governmental employee forecasting overall offshore activities due to altered tax laws.

This environment is one where computerised evaluation models have a large potential as decision support. The purpose of this paper is to describe this planning context and to present the main structure of a field evaluation model (FEM) we have developed over the past six-year period.[1] Presently, it is being used by two governmental agencies in Norway, one international oil firm as well as in our teaching and research.

A large number of decisions must be made throughout the life of a petroleum field. Although FEM may be used for any of them, we will illustrate its potential in the initial field investment decision. At that point in time, petroleum reserves have been estimated from geological data, and the problem is to choose one particular among many alternative ways of developing the field. FEM evaluates the economic consequences of one such alternative.

The three major input categories are field characteristics, financing policy, and tax rules. Each of them is considered separately.

Field characteristics Petroleum production is given by annual quantities of oil and gas. Two profiles for gas may be used, allowing for a differentiation between NGL and natural gas, which are typically priced differently.

Petroleum prices may be stated as a particular series of any shape or generated by one of five mathematical functions. In the latter case, only the parameters of the function are specified, FEM generating the implied price series. Being an easy way of producing many price pattern candidates, it may stimulate a more systematic analysis of energy market scenarios and resulting price structures.[2]

It normally takes three to seven years from the first field development to production startup. During that period, capital costs is the major cash outflow component, subsequently being substituted by operating costs in the production period of 10 to 20 years. In FEM, the two cost categories are individually specified, as they are handled differently at the computation stage. In fact, if larger detail is desirable, separate time series may be stated for up to five platform systems, two petroleum transportation units, and two production wells.

Finally, specific and general price level adjustments can be used, such that any output may be stated in nominal or real terms.

Financing The user states his financing policy in terms of a percent leverage of total cashflow, taking net revenues from operations into account. Leverage may be specified for each year or with one shift over project life. Besides straight loans with equal annual installments, two common options of this industry are included. First, with production payment loans, interest may be paid as a given percentage of oil revenues until final redemption. Second, with a delayed repayment provision, interest and installments are just accumulated and not paid out until production starts. Thus, in the first case, creditors carry a risk of unanticipated changes in petroleum volume or price, yielding a stochastic interest rate even with a zero probability of bankruptcy. In the second case, the time pattern of interest payments is uncertain, but the interest rate is deterministic, given no bankruptcy risk.

Tax rules Offshore petroleum fields are subject to a special-purpose tax system differing widely from that of any land-based activity. Three different tax categories exist, one based on production revenue and two on net income.

First, royalty is a pure barrelage tax levied on the wellhead value of petroleum produced. It is 12.5% for gas and eight to 16% for oil, depending on production volume.[3] Second, regular income tax (IT) is 50.8%. Distributed dividends are deductible for the federal part of IT (27.8 out of the 50.8%), and the depreciation period is six years, provided the field is producing and the asset is being used. Royalty may be expensed and losses carried forwards for no more than 15 years.

Third, the special oil tax (SOT) is 35%, recently up from 25%. Compared to taxable income for IT, dividends cannot be expensed, but 6.67% (formerly 10%) of the 15 previous years' capital costs are deductible. Along with regular depreciation, this so-called uplift makes is possible to deduct capital costs twice for SOT.

The user specifies the various percentages. Due to the depreciation rules, he must also determine when the various assets will be taken into use. Moreover, as historic exploration costs (ie, those occurring before the present

1) The model's name is OFFSHORE–NHH.

2) The single-parameter functions are the linear and exponential ones. Two parameters are required by the parabola and one with linear rise (fall) and fall (rise) with a top (bottom) in between. Finally, in a linear series with one change of growth rates, three parameters are needed. Of course, the constant series may be generated by any of them. It should be stressed that the problem of picking a good price series is external to FEM, which only generates a large number of candidates in an easy way. Ultimately, the user must choose his particular forecast by comparing these series to his knowledge of future petroleum markets.

3) Two points should be noted. First, all three tax categories are based on a standard petroleum price, determined by the government. This may easily differ from the actual selling price reported by the firm in its accounts, and any of the price series options mentioned under field data may be used to forecast these standard prices. Second, any field granted production license before 1972 (ie Ekofisk) pays a flat royalty rate of 10% for both oil and gas.

decision is made) may be expensed in later years, their magnitude must be specified.

To minimise tax payments, FEM calculates maximum payable dividends according to the current law on «reservefondsavsetninger,» (retained earnings required by law), provided the user does not specify a percentage below that maximum.[4]

Obviously, taxes are extremely important for field profitability when on the margin, a dollar of revenue is taxed at eight to 16% and a dollar of taxable income is taxed at 87.5%. Moreover, changes in tax rates or tax systems are essential sources of uncertainty. For instance, two rates in the Norwegian tax law were recently altered, and three modifications have been made in UK rates only during the present Conservative government. Moreover, some structural changes were also considered in the Norwegian case, and the British presently consider introducing a new (ie, a fourth) tax category.

Given this environment, it is essential for both firms and tax law designers to determine economic effects of changes before they are actually made. Clearly, any rate change is analysed by just plugging in different rates. Moreover, structural modifications in tax systems can be studied as well. First, a shift in government policy may cause large discrepancies between actual sale prices and standard prices used for taxation. Second, instead of allowing any leverage and interest cost, the government may introduce a standard leverage and interest cost for tax purposes. Third, several different principles may be used for determining uplift for SOT. All these options are available in FEM.

To ensure that the input part of the model is as flexible and user-oriented as possible, it has been made interactive. This feature makes it particularly easy to specify both the initial base case and subsequent modifications in terms of a sensitivity analysis or a new field. For instance, instead of having to change all the annual input figures for capital costs, operating costs, and petroleum production before running the model, it just asks simple questions to parametrically alter them over selected subperiods.

Given the problem as defined by the input, FEM subsequently computes the various consequences, finally presenting them to the user according to his preferred output mode.[5]

Conceptually, the output may be divided into two parts. At the cashflow stage, consequences are computed year by year. In the criterion part, multi-period cashflow vectors are compressed into a single number by means of some aggregation procedure, like payback period, net present value or most negative cashflow component.

As for financing, the loans raised, interest and installments paid, and outstanding debt at year-end are produced. With a delayed repayment provision, delayed interest and installments are shown separately from the above figures.

Computing royalty is straightforward. For IT and SOT, depreciation is first calculated from capital costs and information about when assets are taken into ordinary use. Starting with production revenue at standardised prices and deducting royalty, operating costs, transportation costs, depreciation, interest, and historic exploration costs, net income before IT and SOT is produced. To calculate IT, deductions for accumulated deficits are made, also expensing dividends for the federal part of IT. Adding back dividends and deducting uplift, SOT is subsequently computed. Finally, if the firm has foreign owners, appropriate adjustments are made in dividend taxes.

Given the net total cashflow generated by a field, there are three interest groups having claims on this total pool. Creditors contribute with loans, getting interest and installments back. The government receives royalty, IT, and SOT, the owners keeping the remaining part of the total. Typically, creditors and owners pay money into the pool in early years, receiving positive amounts later on. Roughly speaking, total tax revenues have the shape of sales revenues, possibly somewhat more skewed towards later years.

By splitting the total into three separate cashflows, the time profile and scale of owner and creditor cashflows are easily compared. Moreover, when discussing the reasonableness or fairness of tax systems, this procedure yields an exact answer to any such «who-takes-what-when» questions by showing the annual split of the total. This feature is essential both for the tax law designer considering new rules and the oil firm arguing for or against particular aspects of tax laws or creditor contracts.

As several evaluation or decision criteria are typically demanded by the user, FEM reports the most common ones of the profession. In most cases, the criterion is produced separately for cashflow to creditors, government and owners. Moreover, like cashflows, the criteria are available in both nominal and real terms.

Maximum balance in the red is the smallest accumulated cashflow. Another criterion reported is payback, discounted at rates specified by the user. Typically, these criteria are not used alone, normally supplementing more accepted ones, like net present value (NPV) or internal rate of return (IRR).

Depending on the nature of input, FEM may be stated in terms of either certainty equivalents (CE) or risk-adjusted discount rates (RADR). In the former case, field data input has been adjusted into CEs, whereas in the RADR version, they are expected values. Moreover, when discounting, riskfree rates are required in the CE version, whereas those of RADR include correction factors for risk as well.

To ensure flexibility in this respect, the user may specify his own set of annual discount rates for each cashflow category. Alternatively, NPV profiles are produced, showing NPVs over a range of different discount rates which are constant over time. Finally, IRRs are calculated.[6]

Once more, the split of the total pool between three interest groups can be studied. As the NPV is additive, it summarises the cashflow split very well by demonstrating how a total NPV is composed of three different values relating to each claim-holder group.

FEM has approximately 4,500 statements and is written in Fortran. Running the model on a DEC 2060 computer takes about three seconds of CPU time. Some output samples from a con-

4) According to the Norway–US tax treaty, Norwegian subsidiaries of US firms (eg, Conoco, Esso, Mobil and Phillips) accumulate «reservefond» according to special rules and pay a «kildeskatt» (dividend tax) on distributed dividends. Moreover, dividends paid from Norwegian firms to others than Norwegians or Americans cannot be deducted for federal IT. As all these rules are included in the model, the nationality of owners must be specified.

5) The user may determine in detail what input and consequences he wants to see. Alternatively, he may choose between nine standard options, number one giving the least output and nine printing close to everything.

6) Clearly, the IRR of creditor cashflow is the effective interest rate. As the tax cashflow contains several positive and no negative elements, the IRR is infinitely large.

structed example are reproduced in appendix 1.

Having recognised the complexity of planning North Sea petroleum fields, this paper has described the economic environment and presented a flexible field evaluation model (FEM).

A distinct feature of FEM is its usefulness in different contexts. Besides serving planning needs of oil firms and solving academic teaching and research tasks, governmental agencies may also benefit. First, economic consequences of safety requirements may be evaluated by the institution producing them. Second, when designing petroleum tax laws, the problem of determining effects on tax revenues and aggregate petroleum activities is too complex to be handled analytically, ie without using numerical examples. The only feasible approach is to test the proposal on real-world field data.

Uncertainty is essential at any level of this planning problem. Thus, instead of adjusting for risk outside the model, like specifying certainty equivalents or risk-adjusted discount rates as an input to FEM, it is relatively easy to transform FEM into an explicit uncertainty model. As reported elsewhere[7], Monte Carlo simulation has been used to generate probability – distributed cashflows and several criteria from stochastic input, like prices or petroleum reserves. An interesting, but often neglected problem that can be analysed with this tool is the risk-sharing properties of tax laws. That is, in an uncertain world, tax systems not only collect fiscal revenue per se (as in a certainty context), is also shifts risk from one interest group to the other. In the referenced paper we used a Monte Carlo extension of FEM to evaluate the relative risk-sharing merits of Norwegian and UK petroleum tax laws. Thus, once more, the applicability of the model at different levels is illustrated.

As usual, FEM only includes certain aspects of the real world, disregarding some potentially important factors. One such omitted candidate is foreign exchange. Because the cashflow components of the problem are typically denominated in several currencies, cashflow risk clearly depends on the currency mix of the data characterising field and financing. Moreover, there are particular tax rules for currency losses and gains which may alter the values as well as rankings of different field alternatives. We have just started incorporating this aspect into FEM.

Petroleum economics is presently an insignificant academic field in Scandinavian countries, especially so for corporate planning issues. We feel, however, that the area is rich on interesting research problems, in particular those relating to long planning horizons and significant uncertainty. Moreover, it seems that many of the problems may be properly solved by applying well known theories of the firm in a particular institutional context. The present model illustrates such an approach.

7) *Ø Bøhren and CM Schilbred «North Sea oil taxes and the sharing of risk – a comparative case study.»* **Energy Econbmics.** *Vol. 2, No. 3 (July) 1980, pp 145–153.*

A) INVESTMENT AND PRODUCTION

	Explor.-costs acc.	Capital-costs	Opera-ting costs	Production		Prices	
				Oil	Gas	Oil	Gas
	Mill.Nkr.	Mill.Nkr.	Mill.Nkr.	Mill.tons	$10^9 m^3$	Nkr./ton	N øre/m^3
1981	400.	540.	0.	0.000	0.0	0.00	0.000
1982	0.	2654.	0.	0.000	0.0	0.00	0.000
1983	0.	4635.	0.	0.000	0.0	0.00	0.000
1984	0.	2948.	37.	0.000	0.0	0.00	0.000
1985	0.	833.	789.	1.600	1.5	1814.20	1.020
1986	0.	883.	837.	4.000	1.5	1959.40	1.102
1987	0.	0.	887.	4.000	1.5	2116.10	1.190
1988	0.	0.	940.	4.000	1.5	2285.40	1.285
1989	0.	0.	996.	3.200	1.5	2468.20	1.388
1990	0.	0.	1056.	2.720	1.5	2665.70	1.499
1991	0.	0.	1120.	2.080	1.5	2878.90	1.619
1992	0.	0.	1187.	1.600	1.5	3109.20	1.749
1993	0.	0.	1258.	0.800	1.5	3358.00	1.889
	400.	12463.	9106.	24.000	13.5		

B) LOANS Mill Nkr

	Annual borrow ing	accrued	Interest delayed	paid	Repayment of loans accrued	delayed	paid	Acc. loans
1981	405.	0.	0.	0.	0.	0.	0.	405.
1982	1968.	41.	41.	0.	0.	0.	0.	2373.
1983	3476.	237.	282.	0.	0.	0.	0.	5849.
1984	2211.	585.	895.	0.	101.	101.	0.	8060.
1985	625.	796.	0.	1790.	593.	0.	694.	7990.
1986	662.	799.	0.	799.	1462.	0.	1462.	7190.
1987	0.	719.	0.	719.	2015.	0.	2015.	5175.
1988	0.	518.	0.	518.	2070.	0.	2070.	3106.
1989	0.	311.	0.	311.	1744.	0.	1744.	1362.
1990	0.	136.	0.	136.	875.	0.	875.	487.
1991	0.	49.	0.	49.	322.	0.	322.	166.
1992	0.	17.	0.	17.	166.	0.	166.	–0.
1993	0.	–0.	0.	–0.	0.	0.	0.	–0.
	9347.	4206.	1218.	4338.	9347.	101.	9347.	

C) TAXABLE INCOME Mill Nkr

	Gross Revenue	Bank's entitle-ment	Depre-ciation	Revenue before taxes	Maxi-mum dividend	To «reserve-fond»
1981	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	–37.	0.	0.
1985	4433.	33.	2330.	–915.	0.	0.
1986	9491.	71.	2077.	4746.	595.	380.
1987	10250.	77.	2077.	5452.	748.	525.
1988	11070.	83.	2077.	6331.	842.	582.
1989	9981.	75.	2077.	5504.	1724.	–172.
1990	9500.	71.	2077.	5185.	1614.	–138.
1991	8417.	63.	147.	6167.	1769.	–110.
1992	7598.	57.	0.	5641.	1635.	–88.
1993	5519.	41.	0.	3836.	1224.	–71.
	76257.	572.	12863.	41752.	10150.	907.

D) TAXES Mill Nkr

	Income tax (max dividend)	Uplift for SOT	Special oil tax (SOT)	Divi-dend tax	Royal-ty	Total govern-ment take (max.div.)	Income tax (0 divi-dend)	Total govern-ment take (o div.)
1981	0.	0.	0.	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	406.	406.	0.	406.
1986	1762.	772.	1057.	89.	961.	3869.	1928.	3946.
1987	2562.	831.	1617.	112.	1038.	5329.	2770.	5425.
1988	2982.	831.	1925.	126.	1121.	6154.	3216.	6262.
1989	2317.	831.	1636.	259.	1018.	5228.	2796.	5450.
1990	2185.	831.	1524.	242.	974.	4025.	2633.	5131.
1991	2641.	831.	1868.	265.	871.	5645.	3132.	5871.
1992	2411.	831.	1683.	245.	697.	5036.	2865.	5245.
1993	1528.	831.	997.	184.	542.	3250.	1869.	3408.
	18388.	6589.	12307.	1523.	7628.	39844.	21209.	41144.

APPENDIX 1: Output samples from a constructed example

Table A gives the field characteristics and prices. Measured in oil equivalents, the project corresponds to about 10% of Statfjord.

The firm is a Norwegian share company with foreign owners. 75% of its capital is financed with debt. The loans have a bank's entitlement of ¾%, 10% straight interest, redemption over six years and deferment provision. The dividend tax is 15%. Numbers are in nominal terms, with an inflation rate of 8%

Tables B to E are a selection of model output. ■

E) PRESENT VALUES AFTER TAX Mill Nkr

Discount rate	Owners	Government	Creditors
0.00	9535.	39843.537	4909.
0.05	6113.	25509.282	2036.
0.10	3872.	16860.930	262.
0.15	2382.	11465.429	– 836.
0.20	1378.	7996.367	–1512.
0.25	895.	5704.543	–1918.
0.30	225.	4152.905	–2151.
0.35	–101.	3078.868	–2271.