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North Sea oil taxes and the sharing of risk – a comparative case study

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The cash flows associated with North Sea oilfields are evaluated in terms of probability distributions of net present value. A simulation shows that, despite structural differences, the ability of the UK and Norwegian oil tax systems to distribute stochastic return between owners and government is remarkably similar. However, a doubled special oil tax would be considerably more consequential in Norway than in the UK, where the effect parallels that of a recent proposal to radically change the tax package. When leverage is increased in either country, rising expected return to equity and falling expected tax revenue are not accompanied by a redistribution of risk from government to owners. Moreover, the governments seem to carry a relatively higher share of price uncertainty.

Any offshore petroleum project involves uncertainty. In economic terms, this means that in any field development programme, nobody can tell the exact shape of the future net cash flow. This is because of the problems of forecasting partially exogenous factors like recoverable reserves, production profile, operating costs or petroleum prices. However, by basing the analysis on probability estimates of such components, the inherent economic uncertainty may be described by a probability-distributed multi-period cash flow, conditional on the decision maker's activities (ie there is a different distribution for each plan). Thus, the economic decision problem is to find the plan yielding the preferred probability distribution.

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In the case of North Sea projects, a second important feature is the presence of extensive legislation. In particular, exploration and production activities are subject to detailed governmental regulation, and special purpose tax systems have been established for several years.

Now consider a field development programme, where uncertain cash flow is described by a probability distribution. This distribution will be split between three groups: equity holders, creditors, and government. Thus, given the stochastic payoff from a field, the tax system may be viewed as a risk-sharing device, distributing the claims to uncertain return between project participants. In other words, it not only collects fiscal revenue *per se* (as in a certainty context) it also determines who carries the inherent risk. Consequently, if the owners are not risk-neutral, the risk-sharing element of petroleum taxation may influence their investment decisions.*

A multinational oil company may normally apply for a development licence in either the UK or the Norwegian sector of the North Sea. When making a choice between these two areas, an essential factor will probably be the

* In a deterministic context, Kemp[1] has previously discussed the ability of petroleum taxation systems to collect pure economic rent. A recent paper by Kemp and Crichton[2] considers, among other things, the Norwegian system's ability to distinguish between marginal and highly profitable fields, using a deterministic model. Basically, the same approach was adopted by Morgan and Robinson who calculated tax revenues under either country's tax regimes.[3,4]

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likely distributions of cash flow to equity holders that would be available in the two countries. Therefore, this issue is also relevant to the respective governments, since dissimilar distributive effects may cause undesirable differences between activity levels in the two countries.

Taxation in Norway and the UK

In both countries, the tax package consists of royalty, corporation tax and oil tax.[5,6]

Royalty

The annual royalty is a pure barrelage tax, based on the year's production of oil or gas. Under the UK system, the royalty is 12.5% of the market value of the annual output.† In Norway, however, royalty is levied on the wellhead value of the oil produced. Moreover, there is a quantity-dependent, progressive royalty scale, the rate ranging from 8% to 16%.‡

Corporation tax

Corporation tax (CT) is 50.8% in Norway and 52% in the UK. Distributed dividends are deductible under Norwegian federal taxation (26.5 out of the 50.8%), whereas they are non-deductible in the UK.§ Moreover, any capital costs can be immediately written off in the UK. In Norway, however, they may be deducted over a period of not less than six years, provided that the field is producing and that the asset is in ordinary use. Whereas royalty is an allowable expense under either system, the oil tax is deductible only in the UK. Finally, any losses may be freely deducted under the UK tax regime. In Norway, losses may be carried forwards (but not backwards) for no more than 15 years, and only one-third of previous years' losses may be used in any particular year.

Oil tax

The oil tax is called Special Oil Tax (SOT) in Norway and Petroleum Revenue Tax (PRT) in the UK, the rates being 25% and 45%, respectively. Distributed dividends are deductible in neither system, and interest is tax deductible only in Norway. Both countries allow for a deduction based on accumulated capital costs. This deduction is called the uplift. In Norway, the uplift is 10% of the 15 previous years' capital costs. Under the UK system, the uplift in any particular year is 75% of that year's capital costs. Finally, the UK tax law incorporates an oil allowance, a safeguard clause and a tapering relief. Due to the oil allowance, annual taxable income may be reduced by the value of 1 million tons of oil, subject to an accumulated maximum of 10 million tons. The safeguard clause relates to a minimum payoff, defined as the difference between the year's cash flow (after interest and royalty, but before CT and PRT) and 30% of accumulated capital expenditures to date. If this minimum is not obtained, no PRT is levied. Otherwise, the tapering relief ensures that PRT never exceeds 80% of the positive difference.

Reviewing the two systems, it seems that although tax categories are identical, the principles behind them as well as the tax rates themselves are rather different. This is not surprising, since when the relevant laws were passed, the oil policies of the two countries served dissimilar objectives.

The primary goal of the UK government was to stimulate a rapid depletion of as many fields as possible, while Norway's policy was aimed at ensuring extended exploitation of the largest and most profitable fields.[7] Therefore, one would also expect dissimilarities between the systems' ability to distribute stochastic payoff between project participants.

Evaluating uncertain multi-period cash flows

It is rare for an uncertain cash flow to have a higher value than another at all times and in all circumstances. Except in such cases, the effects of tax systems cannot be validly evaluated on the basis of cash flow distributions alone.

One solution to this problem is to establish the market prices of the distributions, allowing for a comparison of uncertain cash flows on the basis of their unique, market-determined values. In an idealized world, such an approach is in principle available from the time-state-preference (TSP) model.[8] The same is true of the multi-period version of the capital asset pricing model (CAPM), where the market value of a stochastic cash flow may be expressed as the net present value of the expected cash flow, discounted at risk-adjusted discount rates.[9]

Unfortunately, the data available do not allow for such a theoretically well-founded approach. In the following, we sacrifice theoretical correctness for an evaluation scheme which is feasible. Two stochastic, multi-period cash flows will be compared on the basis of their respective net present values, using a constant discount rate. Return and risk in these distributions will be described by their expectation and standard deviation. In so doing, however, we recognize that such an an approach, which is due to Hillier,[10,11] can be criticized on theoretical grounds,[12] mainly because it is inconsistent with the TSP model.♦[14]

The model and the base case

A strictly analytical approach to the problem would require the establishment of the net present value (NPV)

†From the fifth licensing round onwards.

‡In addition, if any day's production exceeds a particular upper limit, only some of the highest royalty rates will apply to subsequent production.

§However, the UK imputation system reduces the Corporation Tax on dividends to 31.43%.

♦There are several alternative criteria available.[13] One is mean/semi-variance, which associates risk only with outcomes below a predetermined aspiration level. Furthermore, the stochastic dominance criteria use the entire outcome distribution, instead of just its moments. However, like the mean/standard deviation criterion used in this paper, mean/semi-variance as well as stochastic dominance criteria must be considered *ad hoc* under multi-period uncertainty, as they lack theoretical justification. Finally in all cases within our present framework, the definition of risk incorporates 'total risk' and not the 'systematic risk' of TSP or CAPM.

Table 1. Field data for the base case.

Year	Capital costs (million 1979 $)	Operating costs (million 1979 $)	Oil production (million bbl)
1979	422		
1980	505		
1981	751		
1982	798		
1983	518	94	36
1984	178	193	91
1985	84	193	110
1986	28	193	131
1987		193	124
1988		193	104
1989		193	93
1990		193	77
1991		193	66
1992		193	55
1993		193	47
1994		193	40
1995		193	33
1996		144	29
1997		193	22
1998		193	18
1999		193	18
2000		175	15
2001		138	11
Total	3 284	3 446	1 120

distributions directly on the basis of general functions representing field characteristics (capital costs, operating costs, production profile), financial arrangements (leverage, amortization period, interest rate), prospective petroleum prices, and tax schemes. No specific numerical values would appear in this input, allowing for a perfectly general discussion of the resulting NPV distributions (the output). Such an analysis would be carried out by determining the expectation, μ, and standard deviation, σ, of the NPV distributions, using statistical definitions.[15,16]

Looking more closely at the functions in the North Sea oil context, however, the relationship between the inputs to the problem and the μ and σ of the output is too complex to be handled analytically. This is due to the tax rules, which in both countries involve discontinuous functions as well as regulations that cannot even be represented by a function (like the UK safeguard clause and the Norwegian royalty scheme). Moreover, if it had been analytically tractable, the μ and σ of NPV would not necessarily suffice for constructing the complete distribution, even if every stochastic input variable were normally distributed. This follows from the fact that the product of two normally distributed variables (such as price x volume) is not normally distributed.

Recognizing these problems, the present analysis is based on numerical examples, using a simulation model to approximate the true distribution of NPV.[17,18]

Input data

The structure of the field data is very similar to that of the Ninian field,[19] which is a rather large reservoir close to the Statfjord area. The data, based on expected values, are presented in Table 1. In this base case, capital costs are assumed to be deterministic, whereas operating costs, recoverable reserves and production start-up are stochastic variables.

The annual operating costs are normally and independently distributed, the standard deviation being 30% of the expected operating cost up to 1987, 35% from 1988 to 1996 and 40% thereafter. Thus, there is an increasing uncertainty over time. Recoverable reserves are also normally distributed, with an expectation of 1 120 million bbl and a standard deviation of 150 million bbl. Finally, there is a 60% probability of start-up in 1983, whereas 1982 and 1984 are both assigned a 20% chance of being the start-up year.

The future level of oil prices is the fourth and final uncertain component of our problem. Here, two scenarios are used, each with a 50% probability of occurring. In the first one, nominal oil prices increase at 8% per year, whereas in the second scenario, they rise at 12% annually. Today's price is set at $15/bbl, and the annual rate of inflation is assumed to be 6%. Finally, the transportation cost is $1/bbl (1979 $) throughout the entire production period, defining wellhead price as sales prices less transport costs.

As to the relationship between the four stochastic variables, operating costs are tied up with start-up in the sense that the first year of positive operating costs (with an expectation value of $94 million) is always the first year of production, whatever that year turns out to be. Otherwise, there are no dependencies.

Capital costs are 80% financed by debt at an annual cost of 10%, the amortization period being 6 years. No amortization takes place until production start-up.

Net present value of field

From this input, the simulation model approximates the true probability density function for the field NPV as depicted in Figure 1, using deflated cash flows and a 10% real discount rate.¶ Figure 1 shows that any mix of input variables produces a positive NPV at this discount rate.

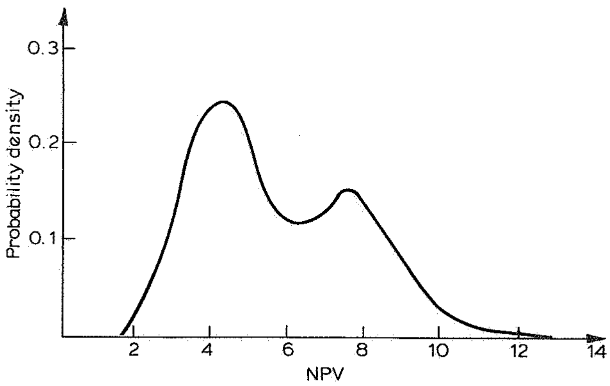

Figure 1. NPV of the base case field.

¶ 10 000 runs were used, since beyond that number of runs, no change in NPV distributions could be observed. To simulate a production profile in a specific run, a total reservoir quantity is first generated. Then, the difference between the simulated and the expected reserve figure is divided by the number of productive years (19). After the annual expected values have been adjusted by the latter ratio, the entire production profile is adjusted in time according to the simulated start-up year. The same time adjustment is made in operating costs.

There is a difference of \$11 billion (10^9) between the largest and smallest NPV attainable, the extremes being \$12.5 billion and \$1.5 billion, respectively.

As to the shape of the distribution, it will be shown below that when price uncertainty is omitted, the bimodal curvature vanishes.** However, this is of course not a general finding; it is caused by the specific numerical values used in the present case study.

The expected NPV, μ, in Figure 1 is \$5.795 billion and the standard deviation, σ, is \$2.019 billion, bearing in mind the problems of representing the economics of an uncertain project by a NPV distribution or only its μ and σ. Of course, this distribution is independent of financial arrangements or tax rules. It represents the payoff from the productive activity, which is to be shared between the three project participants.

As for creditors, it turns out that in all cases the field generates enough cash to repay loan and interest. However, as no amortization occurs until the field is producing, and as neither interest nor principal is secured against inflation, the uncertain start-up makes the real cash flow to creditors a random variable. Moreover, as the real discount rate, the rate of inflation and the nominal interest rate are 10, 6 and 10%, respectively, the NPV of this cash flow ranges from –0.500 to –0.476, the expected value being –0.486†† This very small spread is reflected in the fact that $\sigma = 0.008$.

Thus, although the creditors are exposed to start-up uncertainty, the resulting risk in their NPV is negligible. Consequently, project risk must be carried by equity-holders and government, as what is not taken by one of these two groups is carried by the other. The determinant of this sharing arrangement is the tax law.

Net present value of equity

The distribution for the NPV of equity under the base case tax systems is shown in Figure 2.‡‡ The figure shows that in either country, the bimodal shape of the field NPV reappears in the equity distribution. Moreover, although the Norwegian tax rules seem to leave equity-holders with a slightly higher probability of a large NPV, the general impression is one of a rather remarkable similarity. In Table 2, return–risk effects are compared on the basis of μ and σ.

Because the cash flow from the field is independent of tax rules, the μ and σ of the corresponding NPV distributions are identical in the two countries. As already mentioned, the same is true of the cash flow to creditors in this particular case. From the additive relationship between the expectation of field NPV and that of project participants it is seen that the expected government take is 69.4% in Norway and 71.1% in the UK. Thus, there is correspondingly less left for equity in the UK: \$2.161 billion, as against \$2.259 billion in Norway.

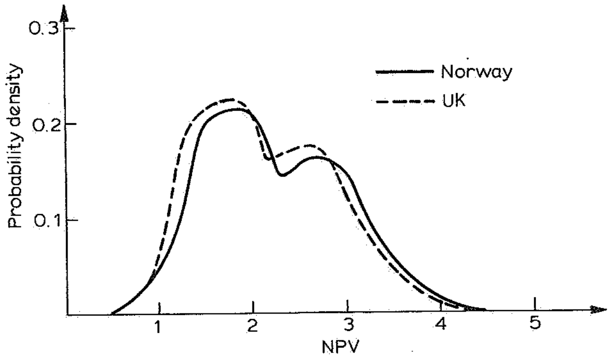

Figure 2. NPV of equity under the Norwegian and the UK tax regimes, base case.

Table 2. Return and risk in the base case (\$ 10^9).

	μ		σ	
	Norway	UK	Norway	UK
The field	5.795	5.795	2.019	2.019
Government	4.022	4.119	1.324	1.395
Equity	2.259	2.161	0.703	0.643
Creditors	–0.486	–0.486	0.008	0.008

Return–risk relations

As for standard deviations, it holds in every case that the larger the expected return, the higher the risk . Thus, the UK government carries a bigger share of total risk than the Norwegian government, whereas Norwegian equity holders take a larger share of project risk than do UK investors.

Comparing return–risk relationships between countries or interest groups, it is seen that there is no case of dominance in the sense that one distribution offers a higher μ and a smaller σ than does any other. Thus, as we only presuppose a general risk aversion in terms of μ/σ, we cannot determine what distributions are the most favourable ones. However, as the (μ, σ) pairs differ so little between countries for owners or government, either interest group should be fairly indifferent between the two distributions in question, even if preference functions within each group are significantly dissimilar.

Therefore in spite of large differences between the tax laws in the UK and Norway, their ability to distribute return and risk seems almost identical.§§

**Simply by demonstrating that when the model is used with a deterministic price equal to the expectation of the stochastic one, the distribution over field NPV becomes unimodal.

††The reason why NPVs are only negative for creditors is that the discount rate applied is higher than the interest rate. Thus, this finding does not mean that the project is necessarily unacceptable to the creditors.

‡‡ Editor's note: In the base case the tax structure in both countries is assumed to be as it was in January 1979. Since that date the tax package in both countries has been altered.

§§It is assumed throughout this paper that to minimize tax obligations, the maximum allowable dividend is paid under the Norwegian tax regime. If no dividend is distributed at any point in time, expected government take rises from 69.4% to 73.4%, and the (μ, σ) pairs of government and owners' NPV become (4.253, 1.385) and (2.028, 0.643), respectively. Thus, compared to the maximum dividend case, expected government income rises by 5.7% and risk by 4.6%. For the owners, the corresponding decline percentages are 10.2% and 8.5% (the effect of personal income taxation is disregarded).

Changing taxes, financing and price uncertainty

Having completed the base case analysis, we now consider sensitivity issues, ie the impact of altered input data. By means of this approach, the robustness to misestimated base case data as well as the more general validity of our tentative conclusions are determined.

Before starting this analysis, however, it seems appropriate to consider the preceding base case study from a sensitivity point of view. Contrasting our simulation model with its deterministic counterpart,[20–23] the former may be thought of as the latter with a stochastic sensitivity analysis built into it. That is, starting out with just point-estimated data in a deterministic model, we specify the range of values that each variable might ultimately take, while simultaneously quantifying the chances that these values will actually turn up. Thus, as compared to a deterministic version, the base case analysis already reflects the potential impact of a very large number of possible outcomes. However, we now go one step further by doing sensitivity analysis on the simulation model. Besides giving information about the impact of data errors in the base case formulation, the approach offers further insight into the risk-sharing effects of tax laws.

Changing the tax rules

In either country, the corporation tax on offshore activities is identical to that of any land-based enterprise, whereas royalty and oil tax constitute the unique features of petroleum taxation. Therefore, when designing fiscal policies that are selectively aimed at the offshore industry, only the two latter tax categories are normally considered.

One straightforward way of altering the tax rules is by modifying tax rates only. Thus, consider the impact of doubled rates, increasing the SOT from 25% to 50% and the PRT from 45% to 90%. As the cash flow from the field and that to creditors are both unaffected, only the NPV of tax revenue and of cash flow to equity are considered.

Consider first the Norwegian case. Figure 3 illustrates the distributions of NPV to equity under 25% and 50%

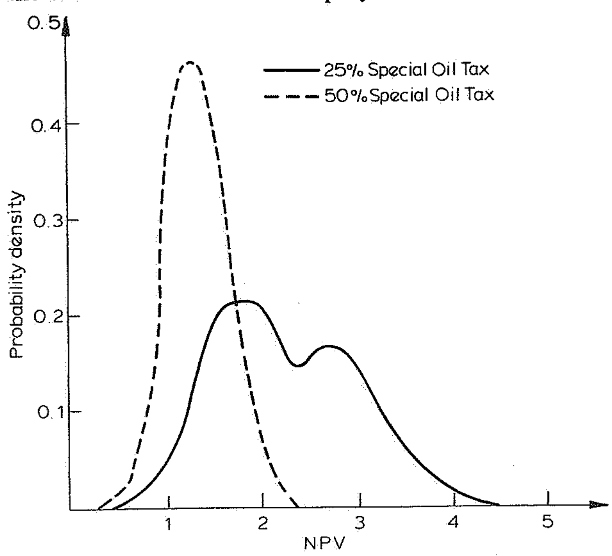

Figure 3. NPV of equity under 25% and 50% Special Oil Tax.

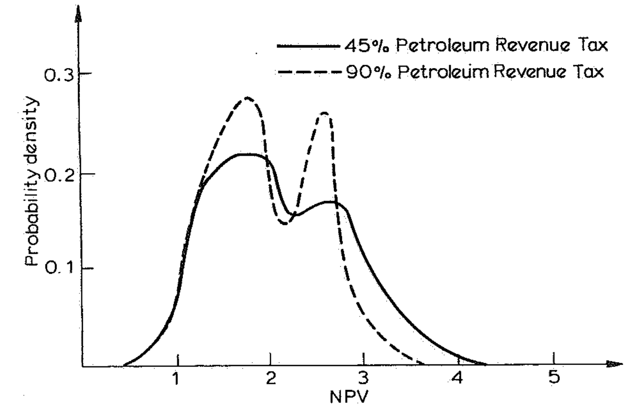

Figure 4. NPV of equity under 45% and 90% Petroleum Revenue Tax.

Table 3. The effects on equity of doubling the SOT and the PRT ($ 10^9).

	μ		σ	
	Norway	UK	Norway	UK
Present rates	2.259	2.161	0.703	0.643
Doubled rates	1.313	1.970	0.310	0.502

SOT. Here, the distribution is shifted to the left, its shape is significantly changed, and its range is halved.♦♦

As can readily be seen from Figure 4, a doubling of PRT in the UK has less dramatic effects. The distribution gets more sharply peaked, but it is still bimodal and practically unchanged in the left portion. Paralleling the Norwegian case, the 90% PRT reduces the probability of large NPVs.

As for tax revenue in the two countries, the probability distributions for NPV are both displaced towards the right of the NPV axis.¶¶ Moreover, they also get more dispersed, reflecting the fact that a higher tax rate increases the tax on a positive taxable income, while simultaneously increasing the tax-reduction effect of a loss or increased costs. Roughly speaking, profitable fields pay more tax under a higher tax rate, whereas unprofitable fields pay less.

Return–risk characteristics, in terms of the distributions for NPV to owners, are reported in Table 3. In the Norwegian case, μ is reduced by 42% and σ by 56% when SOT is doubled, whereas in the UK, the corresponding percentages are 9% and 22% for a doubling of PRT. Comparing these effects on the basis of expected NPV, government take rises from 69.4% to 85.7% in Norway

♦♦In the subsequent discussion of the impacts of tax changes, leverage and uncertainty reduction, the field data for the base case are assumed throughout. This ignores the fact that as tax rules, financial arrangements or price uncertainty changes, the company may consider it worthwhile to either alter its present development programme or to switch over to fields with different characteristics. Thus, we are just evaluating two given plans (ie one particular field development in either Norway or the UK) under alternative assumptions about their economic environments.

¶¶The figures are not reproduced here.

and from 71.1% to 74.3% in the UK. Such a large discrepancy is not very surprising, as the PRT, but not the SOT, is deductible for corporation tax. Moreover, the safeguard clause as well as tapering relief may reduce the impact of an increased PRT rate very effectively.[24]

Thus, if the UK government wants a radical increase in its expected take from a field, altering the PRT rate alone will probably not be enough. The most significant impact may even be in the opposite direction, since relatively more risk will be shifted from owners to government.

There will probably be some modifications to the UK Oil Taxation Act, based on a proposal to revise more than just the PRT.[25] More specifically, one might consider increasing the PRT rate from 45% to 60%, reducing the uplift from 75% to 35%, lowering the annual oil allowance from 1 million tons to 0.5 million tons, while simultaneously reducing the total oil allowance from 10 million to 5 million tons. In Table 4, the effect of this proposal is compared to the straightforward approach of doubling the PRT rate only.***

The combined impact of these changes is almost identical to that of doubling the PRT rate alone. In both cases, the redistribution of expected return from owners to government is not very large, and it may even be neutralized by the relatively larger increase in risk.

Leverage

There are at least two reasons for studying the effects of alternative debt–equity ratios. First, the cash flow to equity depends on the leverage. Second, the tax laws of the two countries treat interest on debt in different ways. Whereas interest is tax deductible in Norway, it is non-deductible for UK PRT.

Starting out from a leverage of 80% in the base case, consider the effects of two smaller ratios, 0% and 65%, and one larger ratio, 95%.

In the present case, the internal rate of return on the field's cash flow after taxes is always larger than the interest rate. Thus, if leverage is reduced, the probability distribution of NPV to equity moves to the left on the NPV axis. Conversely, an increase in the leverage moves the distribution towards higher values. Furthermore, as the project always generates enough cash to repay principal and interest, creditors will only face start-up uncertainty, irrespective of what leverage is used. In the base case, with a leverage of 80%, this risk was negligible. This is also true under the three alternative financing arrangements, implying that practically no total risk is transferred to creditors, irrespective of what share of capital costs is financed by them. In the cases of 0%, 65%, 80%, and 95% leverage, the respective (μ, σ) pairs of NPV to creditors are (0,0), (–0.395, 0.007), (–0.486, 0.008), and (–0.577, 0.010) in both Norway and the UK.

***As the complete distributions are almost identical, they are not reported.

Table 4. The effects on equity of doubling the PRT and of proposed changes to UK Oil Taxation Act ($\$10^9$).

	μ	σ
Doubling the PRT	1.970	0.502
Proposal	1.942	0.504

Table 5. The effect of leverage on equity and expected government take ($\$10^9$).

Leverage (%)	μ		σ		Expected government take (%)	
	Norway	UK	Norway	UK	Norway	UK
0	1.402	1.395	0.695	0.643	75.8	75.9
65	2.101	2.018	0.702	0.643	70.5	72.0
80 (base case)	2.259	2.161	0.703	0.643	69.4	71.1
95	2.416	2.305	0.704	0.643	68.3	70.2

The probability distributions of NPV to government and equity under alternative financing regimes maintain their shape in both countries, the only change being that they are moved upwards or downwards on the NPV axis.††† This is shown in Table 5.

First consider total government take. In Norway, the expected NPV of tax revenue ranges from \$4.394 billion to \$3.956 billion, while in the UK, it decreases from \$4.399 billion to \$4.067 billion as leverage rises from 0% to 95%. Consequently, in an all-equity financed project, tax effects, as measured by expected government take, are almost identical. Moreover, as would be expected, Norway's government take is more sensitive to leverage than that of the UK government. The difference is perhaps surprisingly small, but it may be explained by the fact that although interest is non-deductible for PRT, PRT itself is deductible for corporation tax. Thus, the net effect of taxing an amount of interest, X, is only $0.45X(1-0.52) = 0.216X$ at maximum. In addition, the safeguard clause as well as the tapering relief may further reduce this share.

Turning next to the NPV of cash flow to equity, the standard deviation is seen to be totally insensitive to leverage in the UK and only insignificantly sensitive in Norway. Of course, this is consistent with the previous finding that NPV distributions did not alter their shape as leverage was changed, but were only moved up or down the NPV axis. As for expected values, they rise by \$1.014 billion in Norway and by \$0.910 billion in the UK as leverage increases from 0% to 95%. ‡‡‡Comparing these values to those of the tax revenue, let us finally consider the redistribution of return and risk between owners and government as visualized in Table 6. Because every standard deviation is practically constant across leverage levels, the easiest way of making this comparison is probably by using the return–risk ratio (μ/σ), showing expected return per unit of risk.§§§

We have already established that, as leverage increases, the NPV of cash flow to equity rises at the expense of

†††Again the figures are not reproduced in the present paper.

‡‡‡Of these total gains, reduced taxes contribute 43.2% in Norway and 36.5% in the UK. The rest of the increase stems from the creditors.

§§§Obviously, this does not make much sense if both the numerator and the denominator change simultaneously.

falling NPVs of cash flows to creditors and government. This is fairly obvious. However, as the standard deviation of all three participants' NPV remains almost constant, risk is not shifted correspondingly. Rather, no redistribution occurs. Consequently, as leverage rises in Table 6, the owners of the field face an ever better return–risk ratio, whereas the opposite is true of the government. These effects are almost identical in both countries.

Uncertainty reduction

In the base case, there are four stochastic variables: operating costs; production start-up; total reserves; and petroleum prices. Although each of these contributes to economic risk, a sensitivity analysis of the four distributions reveals that price uncertainty is the crucial one. Therefore, when discussing the effects of uncertainty reduction, the price variable will be transformed from an uncertain into a certain component. That is accomplished by treating the expected price as a deterministic variable in the simulation model. The deterministic scenarios of nominal prices are the expected values of the two uncertain price scenarios, which postulate price increases of 8% or 12% per year, starting from the current level of $15/bbl. As field NPV is a linear function of petroleum prices, it follows from Jensen's inequality that such a transformation will not affect the expected value of this variable.♦♦♦ In that way, only the denominator of the field's return–risk ratio (μ/σ) is changed.

From Figures 5 and 6 it can be seen that in either country, the distribution of NPV to equity changes from a bimodal to a unimodal shape as price uncertainty is disregarded or eliminated. Moreover, the range of the distributions is decreased, reflecting the fact that in the absence of stochastic prices, sales revenue as well as taxable income are more stable. Similar effects may be found in the case of government revenue.

Return and risk under the deterministic price regime are shown in Table 7. The figures disregard the role of creditors, which is unaltered. As for expected values, they are all very close to those of the base case in Table 2. The insignificant discrepancy between the field NPVs in Tables 2 and 7 is due to an approximation error. Moreover, there are very small differences between the corresponding values for government and equity in either country. This implies that the NPV of tax revenue and of cash flow to equity deviate insignificantly from a linear function of petroleum prices.¶¶¶ Thus price uncertainty does not produce changes in expected values, and it is therefore meaningful to compare distributive effects on the basis of the return–risk ratio.

♦♦♦Consider a function f of the stochastic variable X, and let E denote the expectation operator. According to Jensen's inequality, $E[f(X)]$ is larger than, equal to, or smaller than $f[E(X)]$ as $f(X)$ is a convex, linear or concave function. See Ross.[26]

Table 6. Effect of leverage on equity and government revenue (value of μ/σ).

Leverage (%)	Norway Equity	Norway Government	UK Equity	UK Government
0	2.02	3.30	2.17	3.16
65	2.99	3.09	3.14	2.99
80 (base case)	3.21	3.04	3.36	2.95
95	3.43	2.99	3.59	2.91

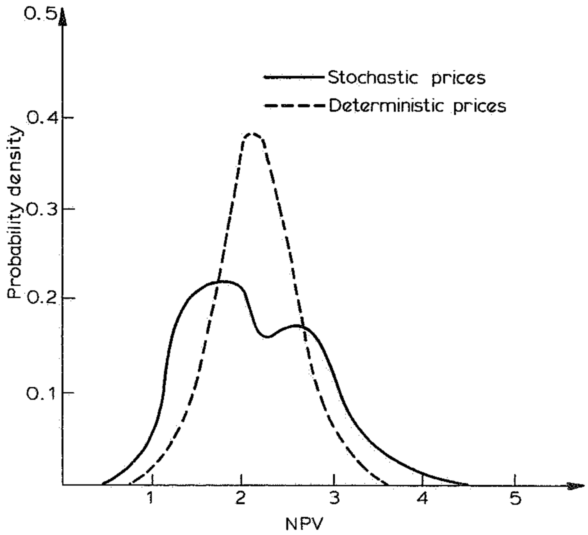

Figure 5. The effect on equity of deterministic prices, UK.

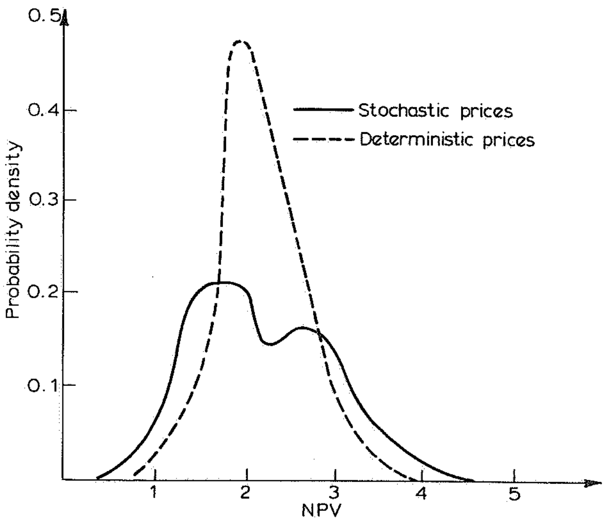

Figure 6. The effect on equity of deterministic prices, Norway.

Table 7. Return and risk with deterministic prices.

	$\mu(\$10^9)$ Norway	$\mu(\$10^9)$ UK	$\sigma(\$10^9)$ Norway	$\sigma(\$10^9)$ UK	μ/σ Norway	μ/σ UK
The field	5.797	5.797	1.096	1.096	5.29	5.29
Government	4.019	4.135	0.705	0.738	5.70	5.60
Equity	2.264	2.148	0.404	0.387	5.60	5.55

¶¶¶ Applying Jensen's inequality (see the previous footnote) to the present case:

In either country, the standard deviation of field NPV or that of tax revenue is almost halved as price uncertainty is removed, whereas the owners reduce their risk by about 40%. Moreover, although each of these two project participants improve their μ/σ ratios, the largest rise in expected return per unit of risk is experienced by the governments.

Conversely, it follows that in terms of return–risk characteristics, both tax systems distribute a relatively larger portion of price uncertainty to the government than to the owners. Thus, whereas in both countries the ratio μ/σ is larger for government than that for owners in the case of certainty, the opposite is true when prices are stochastic.****

Conclusions

We have explored the ability of the Norwegian and the UK tax systems to distribute an oilfield's stochastic payoff between three project participants, ie owners, government, and creditors. Due to the problems of handling this issue analytically, a simulation model was applied, using a specific set of field data, financial arrangements, and petroleum prices. Although the approach may be criticized on theoretical grounds, multiperiod, stochastic cash flows were evaluated through their probability distributions over net present value (NPV), relating the concepts of return and risk to the expectation and standard deviation of these distributions.

In spite of different taxing principles in the two countries, there seems to be a remarkable similarity between their effects on both return expected and risk for every project participant. However, a doubling of the present oil tax rate will be less consequential in the UK, and it may even be that the rise in expected tax revenue is offset by a disproportionally higher redistribution of risk from owners to government. The effects of such a doubling were found to be almost identical to a package changing several components of the UK Oil Taxation Act.

Because Norway's petroleum taxation is more liberal towards interest on debt, one would anticipate changes in leverage to have a stronger impact on owners' expected NPV in Norway than in the UK. However, due to offsetting dissimilarities between the tax systems, the difference almost disappears. In the present case study, where the project always generates enough cash to repay interest and principal at any debt–equity ratio, the expected NPV of cash flow to equity is an increasing function of leverage. However, the tax structure means that the rise in expected value is not accompanied by a corresponding redistribution of risk between owners and government. Thus, by increasing the leverage, equity holders in either country may improve their return–risk ratio at the expense of tax revenue.

In this case study, uncertainty about future petroleum prices made a significant contribution to total field risk as well as to that of owners and government. In either country, government carries a relatively larger portion of price uncertainty than do owners.

Although there are significant differences between the Norwegian and UK tax laws, our analysis suggests that in practice, their impact is remarkably similar. Moreover, it seems that when an industry is characterized by uncertainty, expected or 'best-guess' values alone do not tell the whole story, as tax laws have risk-distributive as well as return-distributive effects.

Thus, on the problem-oriented side, this study draws attention to an aspect of petroleum taxation which is sometimes neglected.

Methodologically, it presents a feasible application of an analytical procedure that has long been contained in textbooks. By realizing the relevance of the problem and the potential of the suggested approach, it is hoped that project participants will be able to improve their decision making (eg when altering tax laws, evaluating new field options or setting credit terms for petroleum loans).

As to the relevance of the specific findings to the entire set of present or future North Sea fields, problems of external validity arise. This occurs because the return–risk issue is not easily tractable on a strictly analytical level, necessitating a case-based approach. In this paper, real field data served as expected values. Our own judgment was used to specify uncertainties about costs, prices, delays and reserves. Supplementing this by a sensitivity analysis, the study therefore covers a substantial range of field characteristics, decision environ-environments and resulting profitabilities. Nevertheless, there are several relevant cases left unexplored, both in terms of field characteristics and the more subjective area of specifying economic uncertainty.†††† Consequently, a useful direction of future research might be to apply the present methodology to a larger variety of North Sea fields and decision environments.

$$f = \sum_{t=0}^{T} \{X_t Q_t - O_t - K_t - g(X_t, Q_t, O_t, K_t')\} (1+i)^{-t}$$

where t denotes time, T is the planning horizon, X is price, Q is quantity, O is operating costs, K is capital costs, K_t' denotes accumulated capital costs up to time t, g is the tax function, and i is the discount rate. Since:

$$\partial f/\partial X_t = (Q_t - \partial g/\partial X_t)/(1+i)^{-t}$$

f is linear in X_t if $\partial g^2/\partial^2 X_t = 0$. In the base case, this is almost true.

****It should be emphasized that every statement about tax law effects made in this paper is of a positive and not a normative nature. We try to analyse the observable return–risk effects of changing taxes and say nothing about how 'fair', 'just' or 'reasonable' a tax law should be.

††††Judging from Kemp and Crichton's analysis, effective tax rates may vary significantly between fields, depending on capital costs as well as petroleum prices. Moreover, there is a relationship between field profitability and tax laws which is not discussed in the present paper. For the UK corporation tax, capital costs from a non-producing field can be deducted from the income of a producing one. This feature, which is not available in Norway, may improve the return–risk position of a marginal field both in absolute terms and relative to a more profitable one, where this cushioning effect is less substantial. To further highlight the risk dimension of this problem, an obvious extension of our model is to treat capital costs as a random variable.

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