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Discounted Cash Flow and Modern Asset Prising Methods – Project Selection and Policy Implications

by

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Discounted Cash Flow and Modern Asset Pricing Methods –Project Selection and Policy Implications*

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Abstract

We examine the differences in the net present values (NPV's) of North Sea oil projects obtained using the Weighted Average Cost of Capital (WACC) and a Modern Asset Pricing (MAP) method which involves the separate discounting of project cashflow components. NPV differences of more than $10m were found for some oil projects. Thus, the choice of valuation method will affect the development decisions of oil companies. The results of the MAP method are very sensitive to the choice of parameter values for the stochastic process used to model oil prices. Further research is recommended before the MAP method is used as the sole valuation model.

JEL Classification: Q4, G0.

Key Words: Discounting, CAPM, Asset Pricing, Oil.

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1. INTRODUCTION

The discounted net cashflow method is still the most commonly used method by oil companies to value oil projects (Siew, 2001). Recent work on the separate valuation of individual cashflows (Jacoby and Laughton (1992), Laughton and Jacoby (1993) and Emhjellen and Alaouze, 2002) offers alternative methods for estimating project VPV. The purpose of the paper is to examine whether oil project NPV's obtained using the discounted cashflow method and a Modern Asset Pricing (MAP) method (Laughton and Jacoby, 1993) are different, and if so to identify any implications this might have for the project selection of energy companies. Finally, we discuss whether a recommendation should be made to change from the WACC discounting method to the MAP discounting method.

We make the assumption that the NPV of the sample portfolio of oil projects calculated using the WACC is correct. The discount rate is based on published estimates of the *ex post* capital asset pricing model (CAPM) betas for two Norwegian oil companies, as described in footnotes one and two. The estimated *ex post* CAPM betas are assumed to reflect the value of the *ex ante* portfolio beta. Given this assumption, and the other assumptions required for the oil price model of the MAP method, an implicit risk factor for oil prices was calculated and used in the MAP oil project NPV calculations. The NPV's of the oil projects were calculated using the MAP method for selected values of the parameters of the oil price model for comparison.

We found that the two discounting methods produced substantially different project NPV’s. This will change company ranking of projects and it will therefore affect the choice of projects. Consequently, both energy companies and the oil and gas producing nations should evaluate the possible impact on project selection and country competitiveness resulting from a change in the project valuation method.

In principle, the MAP approach should give better NPV estimates than the WACC method, because the MAP method discounts revenues and costs using discount rates that reflect the riskiness of each cashflow component. The MAP approach uses a discount rate for revenue that incorporates oil price volatility, risk parameter, mean reversion of oil prices and time.

However, the results of the MAP discounting method are very sensitive to the choice of values for the parameters of the stochastic process used to model oil prices. It is noted that the stochastic process for oil prices cannot be satisfactorily determined from currently available data. It is therefore concluded that more work should be done on the oil price model and the use of risk free discounting of costs, before the MAP method can adopted as the only valuation method.

However, as a complementary model, the MAP method is useful in identifying differences in project NPV related to the cashflow structure of the projects. This is because project NPV's can readily be calculated for a range of values for the parameters of the stochastic process which is assumed to generate oil prices.

The remainder of the paper is organized as follows. Section 2 describes the data used in the paper, the assumptions required for calculating project and portfolio NPV's using the WACC, and discusses the NPV results obtained using the WACC. The MAP methodology and results are discussed in section 3. In section 4, we identify some implications for companies and oil and gas producing nations of using separate cashflow valuation (the MAP method) in calculating NPV. Section 5 presents an assessment of the MAP methodology applied to valuing oil projects. Conclusions are summarized in section 6.

2. VALUATION BASED ON THE WEIGHTED AVERAGE COST OF CAPITAL

2.1 The project data

The oil project data were provided by STATOIL (The Norwegian State Oil Company). The projects are all oil exploration projects in the North Sea and are subject to the Norwegian tax regime. Oil companies are invited to apply for interests in exploration areas when these are made available by the Norwegian government. A normal ownership structure of an oil project is from two to five companies participating in planning and development of the project. One firm, however, is responsible for project development and operation in the production phase.

Data on annual production and (real) investment and operating costs for 14 projects, A through N, together with the aggregate data for the projects (the portfolio) are given in Emhjellen (1999, pp. 92-95), and were also used by Emhjellen and Alaouze (2002). The data are the result of extensive geological work and reservoir simulation. The data were used in the estimation of the expected after tax cashflows and the calculation of the net NPV's of the portfolio of projects and the individual projects.

2.2 Calculating project value - assumptions

The assumptions used in estimating expected after tax cashflows and in calculating present values include the Norwegian tax regime with no time lag for tax payments. Taxes are paid in the year they occur, and tax benefits are received in the year they occur. The assumptions are as follows:

1) A special tax of 50% applied to the offshore oil industry. The actual amount of special tax is based on the tax base, which is equal to: Revenue (R) - Operating cost (OC)- Depreciation tax shield (DTS)- Interest payments (IP)- Additional depreciation allowance (ADA). The special tax is equal to the tax base $\times$ 0.5.
2) An ordinary corporate tax equal to [R-OC-DTS-IP] $\times$ 0.28.
3) Total tax = special tax + ordinary tax.
4) Six-year straight-line depreciation. Depreciation tax benefits can be claimed against other offshore oil revenue of the company. When calculating the expected after tax cost and revenue cashflows, the depreciation amount is treated as a reduction in costs. Thus, depreciation benefits are discounted using the same discount rate as that used in discounting costs, when calculating project and portfolio NPV's using the MAP methodology.
5) An additional depreciation allowance (ADA) of 30% of investment, which is applicable to offshore oil development, treated as 6-year straight-line depreciation. The ADA can also be claimed against other offshore oil revenue. When calculating the expected after tax cost and revenue cashflows, the ADA is treated as a reduction in costs.
   Thus, for NPV calculation purposes, the depreciation allowances from investment in a project can be offset against project or other offshore company revenue. Allowing depreciation amounts to be offset against income generated outside the project implies that negative tax costs can occur in calculating the project and portfolio NPV’s.
6) Expected nominal cashflows (expected cost and expected revenue) were calculated from the data assuming a constant expected inflation rate of 3.5%. All discounting was done on nominal expected cost and revenue data.

7) The nominal risk free rate of return is assumed equal to 6.5%. The effective yield on Norwegian government securities (9-12 months) in August 1994 was 6.39%, up from 5.94% in July (Central Bank of Norway, 1994).

8) The expected oil price was assumed constant at (a real value) of $16US (1994 dollars) per barrel in calculating real oil revenue from the oil production data. The real oil revenue data were converted to nominal revenues using an inflation rate of 3.5%. Apart from the 3-month period, January 1994 through to March 1994, when the average monthly Brent Blend oil price per barrel slipped below $14, the oil price was between $15 to $18 per barrel in1994 (Statistics Norway, "Monthly Bulletin of Statistics" 1995, Table 93).

9) The market risk premium of the CAPM model (Sharpe 1964, Lintner 1965, Mossin 1966) is [E(Rm)-Rf], where E(Rm) is the expected rate of return on the market portfolio and Rf is the risk free rate of return. Johnsen (1991) estimated the nominal market risk premium for Norway at 6%, and this was the value used in this paper.

10) The company is 100% equity financed, which implies that the WACC (Miles and Ezzel, 1980) reduces to the nominal expected required rate of return on equity.[1]

11) The nominal WACC for the portfolio of oil projects is assumed to be 10.5%.[2]

The project NPV's were calculated using the WACC as the discount rate and the NPV of the portfolio was found to be $US 1236.9 million. However, because project I was found to have a negative NPV, it was removed from the portfolio and the NPV of the portfolio changed to $US 1251.3 million. The project NPV's and the portfolio NPV are shown in the third column of Table 3.2.

3. VALUATION USING A DERIVATIVE ASSET METHODOLOGY

3.1 The price model

The present value of a barrel of oil $(V_0(P_t))$ is given by (Laughton and Jacoby, 1993)

$$V_0(P_t) = E_0(P_t) \exp(-\phi\sigma(1-\exp(-\lambda t))/\lambda) \exp(-it), \qquad (3.0)$$

where the risk discount factor is equal to $RDF_t = \exp(-\phi\sigma(1-\exp(-\lambda t))/\lambda)$, the time discount factor is equal to $TDF_t = \exp(-it)$, (with i being the risk free rate), $E_0(P_t)$ is the expected real oil price at time t as determined at time zero, ϕ is the risk adjustment factor of oil prices, σ is the volatility factor of oil prices and λ is the rate of mean reversion of oil prices.

In deriving equation 3.0, Laughton and Jacoby (1993) assume that the only uncertainty in future oil value is due to uncertain oil prices. Their discount rate for expected oil prices accounts for risk, volatility and time. Their discount rate for risk and volatility is given by $\phi\sigma(1-\exp(-\lambda(t-s)))$, where $\sigma(1-\exp(-\lambda(t-s)))$ is that part of the discount rate which accounts for the volatility of expected oil prices at time t, as seen at time $t-s$, (s < t). The parameter σ is a constant, which accounts for short-term volatility and λ is a constant which gives the rate of decay of the volatility of expected oil prices. Risk is introduced by scaling $\sigma(1-\exp(-\lambda(t-s)))$ by the constant ϕ to give $\phi\sigma(1-\exp(-\lambda(t-s)))$ as the discount rate for risk and volatility. The discount rate for expected oil prices at time t as seen at time t-s is given by $\mu_{s,t} = i + \phi\sigma(1-\exp(-\lambda(t-s)))$ and equation 3.0 is obtained from

$$V_0(P_t) = E_0(P_t)\exp\left(-\int_0^t \mu_{s,t}\, ds\right).$$

In the excel spreadsheet model used to calculate project values, the risk discount factor is calculated as[3]

$$RDF_t = \exp(-\phi\sigma(1-\exp(-\lambda t))/\lambda). \qquad (3.1)$$

Risk free discounting for time (TDF_t) is done using

$$TDF_t = \exp(-it)/k_t\,. \qquad (3.2)$$

In equation (3.2), i is the risk free rate and k_t is the inflation factor, which is defined as $k_t = k_{t-1}\exp(k)$, with $k_0 = 1$ and k the constant inflation rate.

3.2 Assumptions

The basic assumptions required for calculating project values are as given in section 1. The additional assumptions are:

1) The short-term volatility of the oil price (σ), which has historically been between 15% and 20% (Kemna, 1993, Pindyck, 1999), is assumed equal to 15%.

2) The mean reversion factor of the oil price (λ) is assumed to be the rate associated with a half-life of 5 years (λ = 0.139). A half life of 5 years for the mean reversion of oil prices was assumed by Laughton and Jacoby (1993) and is the value estimated by Pindyck (1999).

3.3 The cashflow model

Project NPV was calculated using the formula

$$NPV = \sum R_{ct} - \sum C_{ct} - \sum T_{ct} \,, \tag{3.3}$$

where $\sum R_{ct}$ is the sum of the present values of the expected revenue cashflows, $\sum C_{ct}$ is the sum of the present values of the expected cost cashflows and $\sum T_{ct}$ is the sum of the present values of the expected tax cashflows.

The present value of the revenue cashflow at time t, R_{ct}, is equal to

$$R_{ct} = E_0(P_t)Q_t(RDF_t)(TDF_t)k_t, \tag{3.4}$$

where $E_0(P_t)$ is the expected real oil price at time *t*, evaluated at time zero and Q_t is the expected production at time t.

The present value of the expected cost cashflow at time *t*, C_{ct}, is equal to

$$C_{ct} = E_0(C_t^o)(TDF_t)k_t + E_0(C_t^I)(TDF_t)k_t \,, \tag{3.5}$$

where $E_0(C_t^o)$ is the expected real operating cost at time *t* evaluated at time zero, and $E_0(C_t^I)$ is the expected real investment cost at time *t* evaluated at time zero.

T_{ct}, the present value of the tax cashflow at time *t*, is equal to

$$T_{ct} = (R_{ct} - C_{ct}^o - D_{ct}^1)0.28 + 0.5(R_{ct} - C_{ct}^o - D_{ct}^2), \tag{3.6}$$

where D^1_{ct} is the expected (at time zero) present value (PV) of the depreciation allowance for ordinary tax at time t, D^2_{ct} is the PV of the expected (at time zero) depreciation allowance for special tax at time t and $C^o_{ct} = E_0(C^0_t)(TDF_t)k_t$ is the PV of the expected nominal operating cost at time t as determined at time zero. The nominal expected depreciation allowances were calculated as described in section 2.2 and the PV of the nominal expected depreciation allowances were obtained by time discounting only.

A value for the parameter ϕ has to be determined in order to calculate NPV. Assuming that the portfolio NPV obtained using the WACC is correct, a value for ϕ can be obtained from equation 3.0 because the values of all the other parameters in equation 3.0 are known. An estimate of ϕ can be found by iteration using equation 3.0 and Laughton's spreadsheet model. Given the data and the assumptions, ϕ was calculated to be 0.3502. The value of the portfolio NPV obtained using the WACC and which was used to estimate ϕ is $US 1251.3 million, because project I also has a negative NPV using the MAP method.

3.4 Results and comparison

The NPV results for the portfolio obtained using the derivative asset valuation model are shown in Table 3.1. The project NPV’s obtained using the derivative asset valuation model and the WACC discounting model are shown in Table 3.2.

A comparison of the project NPV's obtained using the WACC discounting method with the project NPV's obtained using the derivative asset pricing model shows that the most undervalued projects are projects N (-14 million dollars), G (-12 million dollars) and J (-8.4 million dollars). The most overvalued are projects D (9.3 million dollars), B (8.3 million dollars), C (7.5 million dollars) and E (6.1 million dollars).

The differences in the NPV's of the projects are due to the different time and risk discounting of the individual cashflows by the two models. The WACC discounting method uses a constant annual discount rate to obtain the present value of the expected net after tax cashflows. The risk discount factor in equation 3.0 however, has a time varying component.

The MAP methodology uses different discount rates for each individual cashflow (and period). Thus, negative end period NPV's are possible for some projects. Projects with negative end period NPV's have shorter lives than when the WACC is used in discounting, and the portfolio NPV has to be recalculated. Using the WACC in discounting can lead to overvaluation of the portfolio and the operation of some projects beyond their profitable life. Seven of the thirteen projects were found to have at least one year of negative NPV, when NPV was calculated using the MAP methodology.

Because oil projects are well behaved in the sense that a large part of the cost occurs early in time and production decreases toward the end of the production period, it was found that negative NPV's occurred towards the end of the production period. Projects B, D and J were found to have one year of negative NPV. Projects M and N were found to have two years of negative NPV, while project E had three and project C had four years of negative NPV.

The NPV for the portfolio ($US 1239 million) obtained using the WACC discounting method, after the removal of negative end period NPV's, was used to recalculate ϕ, and the new value of ϕ was calculated to be 0.36014. The project NPV differences using this value of ϕ are given in Table 3.3.

These results show that the difference between the project NPV's obtained using the WACC discounting method and those obtained using the MAP method are more than $US 10 million for projects D (12.0), G (-10.9), and N (-13.2).

Confidence in the project NPV's obtained using the MAP method depends on the belief one has in the specification of the price model and the validity of the separate discounting of the different cashflow components. In Table 3.4 it is shown that the NPV's of the portfolio and the individual projects change substantially when the volatility factor of oil prices (σ), rate of mean reversion of oil prices (λ) and the value of the risk parameter (ϕ) are changed.

The portfolio NPV changes to $US 1590.0 million with $\sigma = 0.1$ and to $US 917.3 million with $\sigma = 0.2$. Changing λ to 0.347 (corresponding to a half-life of two years) gives a portfolio NPV of $US 1708.7 million, changing λ to 0.069 (corresponding to a half-life of ten years) gives a portfolio NPV of $US 958.6 million and a λ of zero gives a portfolio NPV of $US 577.3 million. Setting ϕ at 0.25 instead of 0.36014 gives a portfolio NPV of $US 1559.9 million. The valuation results of the MAP model are therefore shown to be very dependent on the specification of the parameters of the stochastic process, which is assumed to generate oil prices.

4. IMPLICATIONS FOR COMPANY PROJECT SELECTION AND COUNTRY COMPETITIVENESS

Table 4.1 shows that the ranking of the projects differs for the two valuation methods (based on the results of table 3.3). With the separate discounting of cashflows (the MAP method) project D is down from 2 to 3 while project M is up from 3 to 2. In addition project E has moved from 6 to 8 while project G has moved from 8 to 6. The separate discounting of cashflows will therfore affect the decision of which projects to prioritise.

The valuation differences are due to the lower discounting of future cost cashflows as compared to future revenue cashflows and the cashflow patterns of the after tax cost and revenue streams of each individual project. Consequently, development decisions which are based on factors like

1. Offshore or onshore development
2. Reservoir characteristics
3. Production vessel or fixed development
4. Depth of reservoir and/or water depth
5. Closeness to infrastructure and/or processing facilities
6. Fiscal system and tax levels,

which determine investment costs, operating costs, oil production and taxes will cause countries or basins to have apparently more attractive or less attractive projects when valued with separate valuation of cashflows (MAP) as compared to the standard discounted net cashflow method.

Since the present value of cost will be higher with the lower discounting of cost, development solutions that require high operating costs or high investment for long time periods will be disadvantaged with the MAP method. However, with higher discounting for revenues as well, as compared to the standard net discounting method, the net effect on NPV is uncertain.

However, as noted above, providing satisfactory values of the parameters required for the MAP discounting method are available, the MAP approach should give better NPV values for projects than the WACC discounting of net cashflows. This follows because the MAP methodology discounts after tax revenues and costs using discount rates that reflect the riskiness of each component of cashflow.

The tax system in a country will cause large differences in project NPV with the two valuation methods. The NPV differences for the Norwegian offshore tax system are shown in table 3.3. Other tax systems however, may cause even larger differences.

In countries like Brazil, Nigeria and Angola, a foreign company often covers most of the investment cost for the state or for the local state owned company as part of the taxation scheme. In such cases, with the lower separate discounting of the cost cashflow, the additional investment may cause the present value of the investment costs to become large enough to cause the the foreign companies to withdraw from the project, depending on the treatment of tax deductions for depreciation.

5. ASSESSMENT OF THE MAP METHOD FOR CALCULATING OIL PROJECT NPV

The correct specification of the oil price model and its parameters are essential in avoiding valuation errors when using the MAP valuation method. According to Laughton (1998 a), the problems of identifying the oil price model and its parameters have not been solved and may be difficult to solve in the future.

The assumptions of the type of stochastic process and the values of the parameters of the stochastic process generating oil prices are guesses, based on past experience, of how oil prices will behave in the future (Kemna, 1993). Assuming that the stochastic process which generates oil prices, is known, then estimates of the parameters of the stochastic process must be obtained.

In the oil market there exists no long-term market trading in oil (long term in this context is the next 10 to 20 years), therefore the volatility parameter (σ) cannot be calculated. Estimates based on past data will depend on the time period selected (Figlewski, 1997) and the problem becomes which estimate to choose as an estimate for the *ex ante* value of σ.

Mean reversion of oil prices is a feature of the MAP methodology of Laughton and Jacoby (1993) and is also assumed to hold by Wey (1993) and Baker *et al.* (1998). Laughton (1998 b) comments as follows on the treatment of mean reversion in oil prices found in Laughton and Jacoby (1993): "A compelling case is made that some sort of price reversion is occurring in oil markets. However... there are problems with the application in some situations of the simple reverting price model presented in Laughton and Jacoby (1993). If this model holds, then the reversion is strong enough that commodity owners will not find it optimal to sell their stock, let alone produce a stock of the commodity to sell, unless the price is substantially above the long-term trend. This is not a consistent market price model if there is no supply side over most of the range of possible prices. Further research is required into the use of such models in practice, particularly in situations where indefinite waiting is possible".

This suggests that the principal usefulness of the MAP method is that it provides a methodology for computing project NPV's for selected values of the volatility parameter (σ), the mean reversion of oil prices parameter (λ) and the risk parameter (ϕ). Once base values of these parameters are chosen, oil project NPV's can be calculated for selected values of these parameters. This should provide a useful analysis of the dependence of oil project NPV on the values of the parameters of the stochastic process, which is assumed to generate oil prices.

6. CONCLUSIONS

The use of the MAP method for practical oil project valuation may lead to better oil project NPV estimates, because the MAP discounting method takes into account the tax system and the risk structure of the project cashflows in discounting oil revenues and costs. However, NPV estimates obtained using the MAP method are very sensitive to the choice of parameter values for the stochastic process used to model oil prices. Therefore, more research on the oil price model and the validity of its assumptions is required before one can confidently replace oil project valuation based on the WACC, with oil project valuation based on the MAP methodology.

The MAP method can, however, provide a useful sensitivity analysis of the dependence of oil project NPV on the values of the parameters of the stochastic process which is assumed to generate oil prices.

The separate discounting of individual cashflows, with lower discounting of the cost cashflow, will affect oil project NPV. This effect on value will be different for individual oil projects depending on the physical characteristics of the reservoir, the development plan and the tax system. Consequently, if the MAP methodology becomes the preferred method of oil project valuation, countries will have to examine the impact on their oil project portfolio of the timing and value of taxation depreciation allowances. This follows because the treatment of depreciation tax deductions as a reduction in costs in the MAP discounting methodology, where costs are discounted using a lower discount rate than revenues, means that project NPV is particularly sensitive to the treatment of depreciation for tax purposes.

Footnotes

1. The weighted average cost of capital for an asset is given by: $WACC=E(R_e)(E/(E+D))+E(R_d)((1-\gamma)D/(D+E))$, where: $E(R_d)$ is the expected required rate of return on debt (estimated from the rate paid on new issues of long term company bonds), γ is the marginal corporate tax rate, E is the market value of equity (estimated by the total number of outstanding shares times the share price), D is the market value of debt (estimated by the market value of company securities minus the market value of common stock) and $E(R_e)$ is the expected required rate of return on equity (estimated using the risk free rate of return plus the market risk premium for the asset given by the CAPM model). When D =0, the WACC reduces to the expected required rate of return on equity (Copeland and Weston 1992, Brealy and Myers 1991).

2. The value of 10.5% for the WACC is close to that estimated for the Norwegian oil companies Saga Petroleum and Norsk Hydro using the unlevered betas for the companies. There is a simple relationship between the levered and unlevered betas for an asset given the assumptions of the CAPM. $B^L=B^U[1+(1-\gamma)D/E]$, where B^L is the levered beta, B^U is the unlevered beta and γ , D and E are as defined in footnote 1 (Butters *et al*. 1987).

The levered betas of the Norwegian oil companies Saga Petroleum and Norsk Hydro were given in the Norwegian financial newspaper "Dagens Næringliv" on the 30th of December 1994 as 0.9 and 1.0 respectively. The unlevered beta of Saga Petroleum was calculated to be 0.7121, and the unlevered beta of Norsk Hydro was calculated to be 0.7080.

The unlevered betas were estimated using the formula in footnote 1. A market debt/equity ratio of 119.92% (based on share price, number of outstanding shares and outstanding debt at the end of 1994), and a marginal tax rate of 78% were used to calculate the unlevered beta for Saga petroleum.

A market debt/equity ratio of 80.08% (based on share price, number of outstanding shares and outstanding debt at the end of 1994) and an average marginal tax rate of 48.5% were used to calculate the unlevered beta for Norsk Hydro.

The average marginal tax rate of Norsk Hydro was calculated by allocating company debt according to the operating results of its four divisions for the year 1994. This involved claiming 55% of the interest on debt (three of the divisions) against the onshore marginal tax rate (28%), and 45% of the interest on debt against the offshore marginal tax rate (78%).

With the above assumptions, an unlevered beta of 0.71 would give a WACC of 10.76% (10.76%=6.5% + 0.71 x 6%). Thus, the WACC assumed for the portfolio of oil projects is very close to the WACC of the two representative oil companies calculated using the unlevered betas of these companies.

3. This spreadsheet model was presented by D.G. Laughton, at the Norwegian Petroleum Directorate, Workshop on Modern Asset Pricing and Project Evaluation, Stavanger, Norway, May, 1997. Laughton’s spreadsheet model was used to calculate the implicit discount factors described in Salahor, 1998.

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Table 3.1: Portfolio NPV using the MAP method

	NPV Certainty Equivalent A.Tax C.F.	PV Certainty Equivalent Pre Tax C.F	PV Certainty Equivalent Revenue C.F.	PV Certainty Equivalent Cost C.F.	PV Certainty Equivalent Tax C.F.
Sum	1251.3	5198.1	19072.2	13874.1	3946.8
t					
0	-96.9	-122.7	0.0	122.7	-25.8
1	-682.8	-813.6	69.5	883.1	-130.8
2	-1342.7	-1650.3	237.8	1888.1	-307.6
3	-1036.1	-1478.3	484.6	1962.9	-442.2
4	-404.2	-301.0	1652.1	1953.1	103.1
5	689.1	1192.7	2429.2	1236.5	503.6
6	1043.7	1706.4	2612.1	905.7	662.7
7	1056.6	1704.7	2361.4	656.7	648.1
8	809.6	1409.4	1976.0	566.6	599.8
9	483.1	1018.2	1591.3	573.1	535.0
10	250.5	714.7	1214.9	500.2	464.2
11	160.4	522.0	935.5	413.5	361.5
12	100.7	383.4	774.2	390.8	282.8
13	69.3	276.9	649.7	372.8	207.6
14	49.6	189.8	546.3	356.5	140.2
15	36.0	149.0	439.3	290.3	113.0
16	26.2	118.9	363.7	244.8	92.8
17	20.4	92.6	289.1	196.4	72.3
18	14.8	67.2	254.8	187.6	52.4
19	4.4	20.1	118.4	98.3	15.7
20	1.2	5.5	45.5	40.1	4.3
21	-1.7	-7.5	26.8	34.3	-5.9

The present value cashflows in Table 3.2 were calculated using Laughton's model, the portfolio data less project I and $\phi = 0.3502$. The after tax net present value cashflow values are in column 2, the pre-tax present values in column 3, the present value revenue cashflows in column 4, the present value cost cashflows in column 5 and the present value tax cashflows in column 6. The sum value row shows the aggregate value of the individual columns where the net present value of the portfolio is shown in column 2 (1251.3). All numbers are in million $US.

Table 3.2 NPV comparison (Negative end period cashflows included).

Model nr.	1	2	nr.2-nr.1
	MAP	WACC	
Project			Difference
A	62.1	63.3	1.1
B	99.2	107.5	8.3
C	42.8	50.3	7.5
D	130.2	139.4	9.3
E	59.6	65.7	6.1
F	24.8	26.7	1.8
G	70.1	58.1	-12.0
H	30.0	30.5	0.6
J	127.9	119.5	-8.4
K	12.4	13.2	0.8
L	19.2	17.0	-2.2
M	136.2	137.3	1.1
N	436.8	422.7	-14.0
Portfolio	1251.3	1251.3	0.0

Net present values obtained using the data minus project I.

Table 3.3: Net present value differences using the WACC discounting method and the derivative asset pricing model with $\phi = 0.36014$.

Model nr.	1	2	nr.2-nr.1
	MAP	WACC	
			Difference
Project			
A	61.0	63.3	2.3
B	98.3	106.3	8.0
C	44.4	45.7	1.3
D	127.0	139.0	12.0
E	59.6	64.2	4.6
F	24.3	26.7	2.4
G	69.0	58.1	-10.9
H	29.6	30.5	0.9
J	125.4	118.8	-6.6
K	12.2	13.2	1.0
L	18.8	17.0	-1.9
M	136.0	136.0	0.0
N	433.4	420.2	-13.2
Portfolio	1239.000	1239.0	0.0

NPVs were obtained using the data without project I and negative end period net present value cashflows.

Table 3.4: Project and portfolio NPV's obtained using the MAP method with different estimates for the parameters.

Project	Base	Sigma		Rate of mean reversion			Value of ϕ
		0.10	0.20	0.347	0.069	0.000	0.250
A	61.0	75.0	48.0	77.1	52.7	42.1	73.8
B	98.3	129.2	70.0	139.2	75.0	44.1	126.5
C	44.4	75.2	16.1	86.0	20.1	-12.4	72.6
D	127.0	188.4	71.6	222.3	62.1	-31.9	183.1
E	59.6	82.0	39.0	89.1	42.8	20.7	80.1
F	24.3	31.1	17.9	32.3	20.1	14.9	30.6
G	69.0	83.5	55.6	88.7	56.9	40.3	82.3
H	29.6	34.1	25.5	35.2	26.4	22.1	33.7
J	125.4	172.7	82.2	191.1	85.6	31.2	168.7
K	12.2	15.1	9.5	14.8	11.0	9.6	14.8
L	18.8	23.0	14.9	21.7	17.6	16.3	22.6
M	136.0	166.1	108.2	171.3	117.1	92.6	163.5
N	433.4	514.6	358.8	539.8	371.2	287.5	507.6
Portfolio	1239.0	1590.0	917.3	1708.7	958.6	577.3	1559.9

The base NPV's are as in Table 3.4, where the price model parameters are $\phi = 0.36014$, $\sigma = 0.15$ and $\lambda = 0.139$ (corresponding to a 5 year half life). When $\lambda = 0$, the risk adjustment factor becomes $RDF_t = \exp(-\phi\sigma t)$ (compared to equation 3.1) and the valuation method reduces to that described in Jacoby and Laughton (1992).

Table 4.1: Ranking of the oil projects from the results in table 3.3.

Ranking	WACC Discounted Cashflow method	MAP valuation method
1	N	N
2	D	M
3	M	D
4	J	J
5	B	B
6	E	G
7	A	A
8	G	E
9	C	C
10	H	H
11	F	F
12	L	L
13	K	K