Financial analysis of an oil field

Background

After initial exploration and appraisal, a major oil company has estimated the reserves in a new oil field which it plans to develop as 300 million barrels of oil equivalent. The oil company plans to develop this field over the next five years (starting 2025) with production starting in 2030 and decommissioning of the field expected in 2046.

The discount rate is assumed to be constant over time and equal to 8%, whereas the government of the country in which the oil field is being developed is currently charging a corporate income tax rate of 35%. The corporate income tax is levied on the Net Cash Flow (NCF), rather than revenues, and only once the cumulative cash flows become positive. Moreover, when the cumulative cash flows are positive but below the NCF for the current period, the tax is charged on the positive cumulative cash flows.

Introduction

The objective of the study is to determine whether the oil field is viable based on its net present value. This is done using a financial model based on fixed inputs (with no uncertainty) and compared with the results of a Monte Carlo simulation of oil price assuming a uniform distribution, and two log-normal distributions based on historical data.

The fixed inputs model suggests that the project has a positive NPV and is therefore worthy of investment. This is confirmed by the sensitivity analysis, which shows that if each parameter is changed by up to 50% in isolation, only a fall in oil prices is enough to change the investment decision (see Figure 7/8).

When a Monte Carlo simulation is introduced, assuming a uniform distribution for oil price and keeping all other variables fixed, the probability of a positive NPV is estimated at 78% based on 1000 trials, which supports the decision to invest.

Oil prices are unlikely to follow a uniform distribution, so further Monte Carlo simulations were run based on historical oil price data and assuming a log-normal distribution. Using nominal prices from 1974 to 2024, the probability of a positive NPV is estimated at only 40%. This is compared with inflation-adjusted prices, which estimate an 87% chance of a positive NPV.

Description of models and analysis undertaken

The models are separated across two workbooks: the fixed input model and the Monte Carlo simulation models. In some models, oil prices were fixed, in others dynamic, so separating them made it easier to avoid mistakes.

The base case inputs for all models are summarised below:

Inputs	Base case
Base year	2025
Development start	2025
Production start	2030
Decommissioning start	2044
Discount rate (WACC)	8%
Total field production (MMbbl)	300
Field cost inflation	1.25%
Development expenditure (DevEx; $/bbl)	15
Production cost (OpEx; % of accumulated DevEx)	7%
Decommissioning cost ($/bbl)	2
Oil price ($/bbl)	60
Oil price inflation	2.25%
Corporate income tax	35%

Figure 1. Summary of base case inputs for all models. (Note: Oil price is not constant in Monte Carlo models). All hard-coded values are blue.

Each model assumes that if production costs are greater than revenue for a given year, production will still continue. This may not reflect reality but can easily be adjusted. Each also assumes no covariance between oil price and other variables, which is unrealistic, but allows the model to be less complex. Finally, each assumes that oil price is fixed with a constant yearly inflation, rather than following a random walk. This is also unrealistic, but simplifies the model.

Fixed inputs model

The results from the fixed inputs model are compiled into a sensitivity analysis, tornado diagram and scenario analysis to determine which inputs had the largest impact on NPV. Variables that are deemed not consequential enough to model in a sensitivity analysis (e.g. field cost inflation) are excluded, as are dates associated with production, development expenditure, and decommissioning.

A multivariate sensitivity analysis is run on the two most consequential variables (oil price and development expenditure), and on two variables assumed to be uncorrelated (oil price and corporate income tax).

A scenario analysis simulates two outcomes: in a recession, I assume a 10% decrease in input prices, while for an economic boom I assume a 10% increase. It's unlikely that many inputs would move 10% in a recession (e.g. corporation tax or discount rate—depending on the cause of the recession, both could move in a different direction), but the alternative was to arbitrarily change the value of each input, which would have brought a new set of problems.

All subsequent models build on the fixed inputs model but modify the oil price distribution. They are built using a Monte Carlo simulation of 1000 trials, with oil price drawn randomly according to the appropriate distribution.

Oil price – uniform distribution

The uniform model assumes the same fixed inputs, except for oil price, which could take a range of values from $20 to $100/bbl with equal likelihood.

Oil price (uniform)	
Mean	60.37
Standard Error	0.74
Median	60.76
Standard Deviation	23.55
Sample Variance	554.39
Kurtosis	-1.23
Skewness	-0.01
Range	79.98
Minimum	20.02
Maximum	99.99
Sum	60365.82
Count	1000

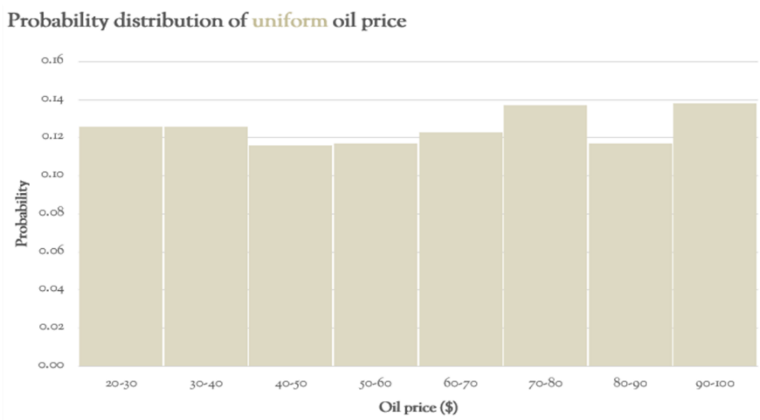


Figure 2. Summary statistics and probability distribution of the uniform oil price model. Results were generated using a Monte Carlo simulation; 1000 trials.

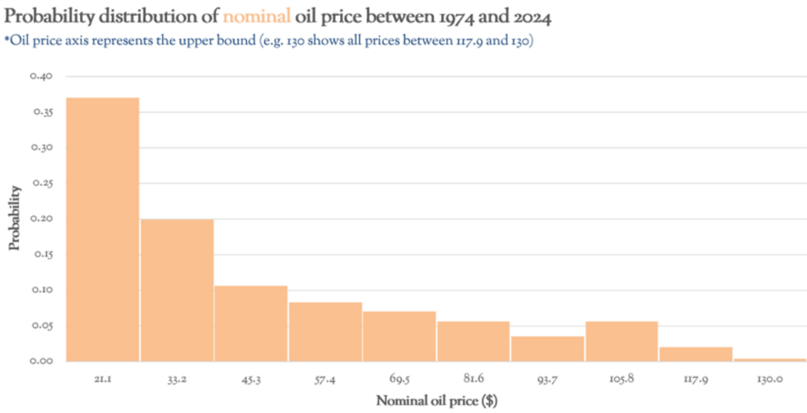
Oil price – log-normal distribution

To better model the oil price, I use a log-normal distribution based on monthly oil prices between 1974 and 2024 (EIA, 2024). A shorter period could have been chosen, but I wanted to include the volatility associated with the oil shocks of the 1970s and the bust of the early 1980s, when a dollar was worth more than a dollar today, all oil prices are based on inflation-adjusted prices compiled by the US Energy Information Administration (EIA).

Figure 3. A comparison of nominal and inflation-adjusted oil price data from 1974 to 2024. The period from 1974 to 1986 appears to be as volatile as the 2008 to 2016 period, yet in nominal terms the effect is hard to observe. (Source: EIA, 2024)

As Figure 4 shows, both the nominal and inflation-adjusted oil price data have a right-skewed distribution, suggesting that a log transformation would be appropriate. Note that the distributions are noticeably different, particularly regarding the mean (and median), which would greatly impact our model accordingly.

Nominal oil price ($)	
Mean	39.60
Standard Error	1.14
Median	28.80
Standard Deviation	27.98
Sample Variance	783.06
Kurtosis	0.10
Skewness	1.09
Range	118.38
Minimum	9.39
Maximum	127.77
Count	602



Inflation-adjusted oil price ($)	
Mean	72.15
Standard Error	1.36
Median	70.55
Standard Deviation	33.40
Sample Variance	1115.52
Kurtosis	-0.30
Skewness	0.67
Range	163.87
Minimum	17.79
Maximum	181.66
Count	602

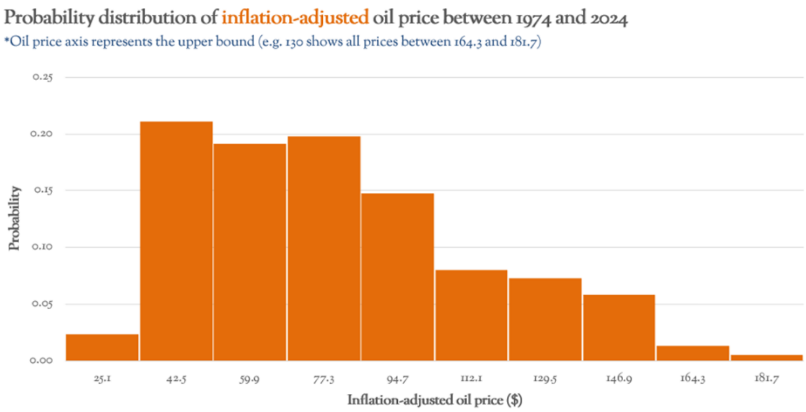
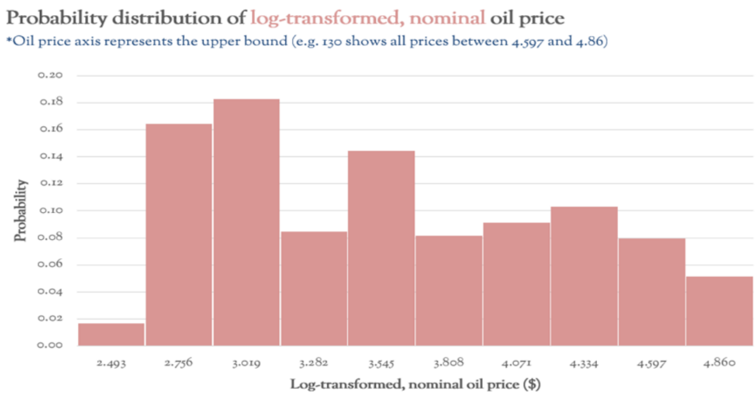


Figure 4. Summary statistics and probability distributions of nominal (above) and inflation-adjusted (below) oil prices taken monthly between 1974 and 2024. Note that the axis values for each figure are different, but both appear to show a log-normal distribution. The cumulative distributions for each can be found in the attached Excel sheet.

The log-transformations of the inflation-adjusted and nominal data are below.

Log(nominal oil price)		
Mean	3.45	31.43
Standard Error	0.03	
Median	3.36	
Standard Deviation	0.67	1.96
Sample Variance	0.45	
Kurtosis	-1.14	
Skewness	0.31	
Range	2.61	
Minimum	2.24	
Maximum	4.85	
Count	602	



Log(inflation-adjusted oil price)		
Mean	4.17	64.66
Standard Error	0.02	
Median	4.26	
Standard Deviation	0.48	1.61
Sample Variance	0.23	
Kurtosis	-0.76	
Skewness	-0.14	
Range	2.32	
Minimum	2.88	
Maximum	5.20	
Count	602	

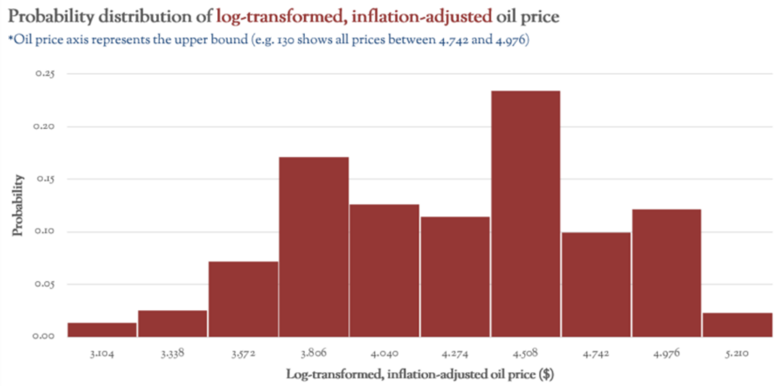


Figure 5. Summary statistics and probability distributions of the log-transformed nominal (above) and inflation-adjusted (below) oil prices. Both now appear to show a less skewed, more "normal" distribution. Note that axis values are different for each figure.

For the purpose of the model, these distributions are used to estimate the oil price in Year 0, which then is assumed to remain stable over time.

Results

The results of the fixed inputs model and the Monte Carlo simulations under different oil price assumptions will be discussed separately.

Fixed inputs model

A summary of the results is below:

Summary	
NPV (pre-tax; $M)	4999.9
NPV (post-tax; $M)	2858.8
IRR (post-tax)	21%
NPV (DevEx; $M)	3884.7
Return on investment (ROI)	74%

Figure 6. Summary of the NPV under the assumptions of the fixed input model. Post-tax NPV is high, at $2858.8 million, with a return on investment of 74%.

The sensitivity analysis shows that a 50% change in a negative direction for each variable (in isolation) except oil price is not enough to send the post-tax NPV below zero, and therefore would not change the investor's decision. A 50% change in the oil price (to $30), however, would lead to a negative NPV, suggesting the NPV is most sensitive to a change in oil prices.

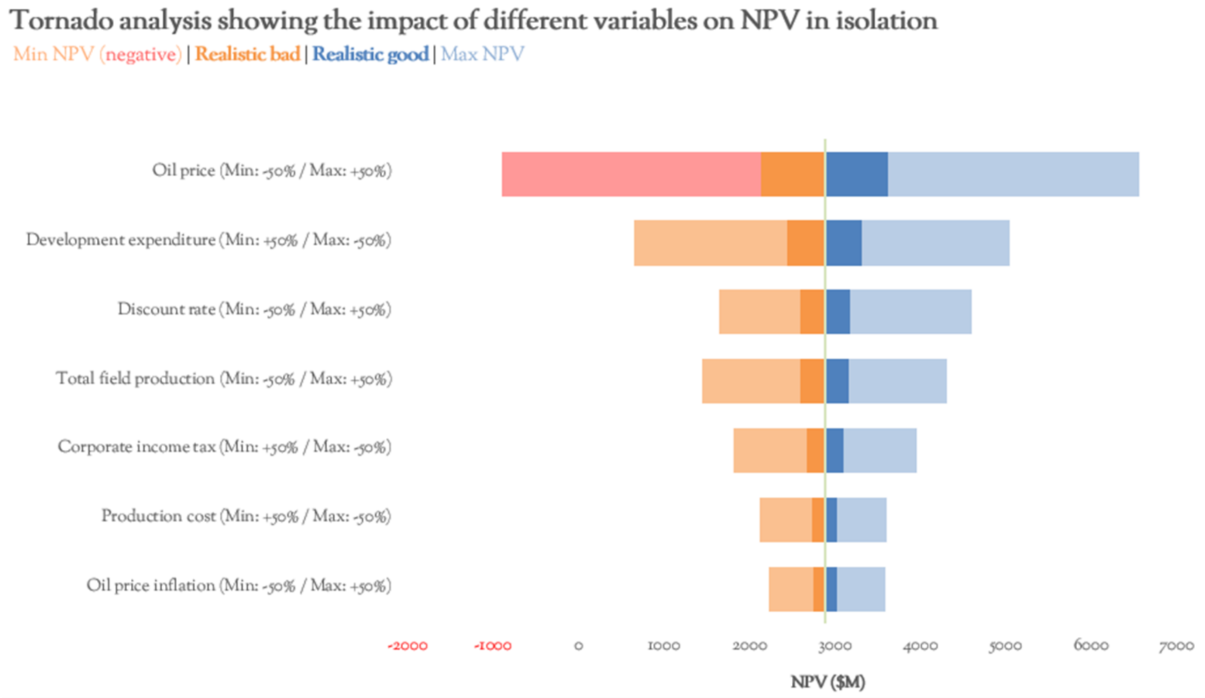


Figure 7. Tornado analysis of selected inputs in the fixed input model.

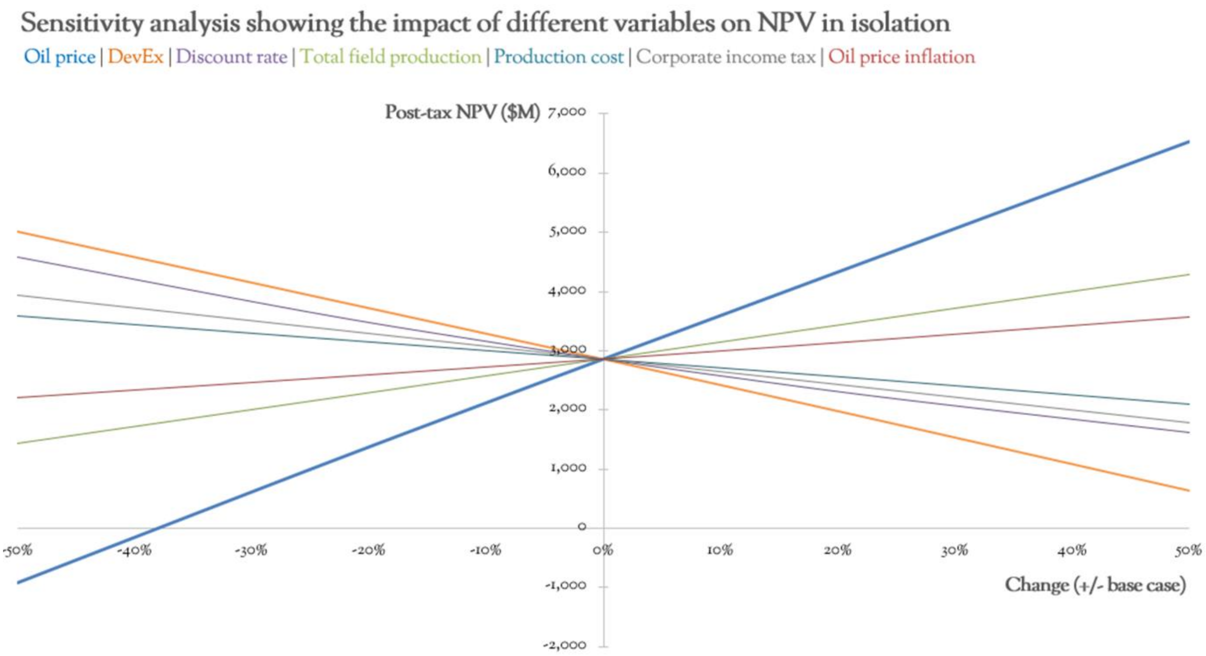


Figure 8. Sensitivity analysis of selected inputs in the fixed input model.

NPV 2858.8	Oil price ($/bbl) 30	45	54	60	66	75	90
Development Expenditure ($/bbl)							
7.5	1346.8	3183.7	4285.8	5020.6	5755.4	6852.5	8679.6
11.25	233.2	2102.8	3204.9	3939.7	4674.5	5776.6	7613.5
13.5	-455.5	1442.1	2556.4	3291.2	4025.9	5128.1	6965.0
15	-921.5	995.7	2118.6	2858.8	3593.6	4695.7	6532.6
16.5	-1397.7	545.4	1674.8	2421.4	3161.2	4263.4	6100.3
18.75	-2139.2	-137.7	1003.8	1755.8	2503.3	3614.8	5451.7
22.5	-3658.1	-1299.6	-132.2	631.8	1388.2	2513.7	4370.8

NPV 2858.8	Oil price ($/bbl) 30	45	54	60	66	75	90
Corporate income tax (%)							
18%	-770.9	1592.8	2997.2	3929.4	4858.8	6252.9	8576.4
26%	-846.2	1294.3	2557.9	3394.1	4226.2	5474.3	7554.5
32%	-891.4	1115.1	2294.3	3072.9	3846.6	5007.2	6941.4
35%	-921.5	995.7	2118.6	2858.8	3593.6	4695.7	6532.6
39%	-951.6	876.3	1942.9	2644.7	3340.5	4384.3	6123.9
44%	-996.8	697.2	1679.3	2323.5	2961.0	3917.1	5510.7
53%	-1072.1	398.7	1240.0	1788.2	2328.4	3138.6	4488.9

Figure 9. Multivariate sensitivity analyses of oil price vs development expenditure (above) and oil price vs corporate tax (below). Oil price and development expenditure are assumed to be positively correlated, so only relevant values are highlighted.

The scenario analysis shows a healthy post-tax NPV in both recession ($2738 million) and boom ($2884 million).

Variable	Recession	Base case	Economic boom
Oil price (R: -10% / B: +10%)	54	60.0	66.0
Development expenditure (R: -10% / B: +10%)	13.5	15.0	16.5
Discount rate (R: -10% / B: +10%)	0.072	0.08	0.088
Total field production (R: -10% / B: +10%)	270.0	300.0	330.0
Corporate income tax (R: -10% / B: +10%)	0.315	0.35	0.385
Production cost (R: -10% / B: +10%)	0.063	0.07	0.077
Oil price inflation (R: -10% / B: +10%)	0.0203	0.0225	0.0248

NPV ($M)	Recession	Base case	Economic boom
Post-tax NPV	2738.8	2858.8	2884.0
Pre-tax NPV	4409.7	4999.9	5551.5

Figure 10. Scenario analysis showing the effect on NPV of recession and economic boom scenarios.

Monte Carlo models

To simulate a random oil price with a uniform distribution between $20 and $100, I used the following formula:

*=MC_min_oil_price_uniform+((MC_max_oil_price_uniform-MC_min_oil_price_uniform)*RAND())*

To simulate a random oil price based on a log-normal distribution, I used the following formula, applying theory from Thomopoulos (2012, p. 40):

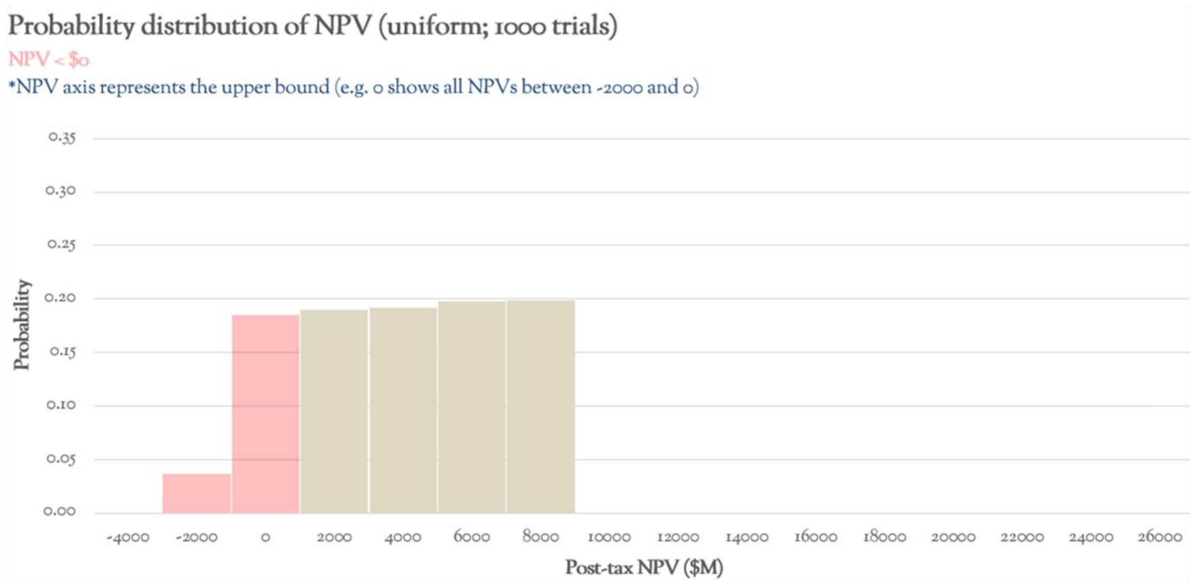
=EXP(mean_oil_price_infl_adj_log_transformed+std_dev_oil_price_infl_adj_log_transformed(NORMSINV(RAND())))*

This is calculated by multiplying the standard deviation of the log-transformed oil price by a z-value (the percentile on a standard normal curve between 0 and 1), then adding that to the mean of the log-transformed price, all of which is then exponentiated to reverse the log transformation.

A summary of the results from each model is below:

Uniform model

Summary statistics	Oil price	NPV ($M)
Mean	60.4	2863.0
Median	60.8	2951.6
99th percentile	99.4	7686.2
75th percentile	80.5	5363.3
25th percentile	39.9	354.1
1st percentile	20.9	-2318.1
Maximum	100.0	7756.4
Minimum	20.0	-2490.4
Sample size	1000	
P(oil price < $30/bbl)	13%	
P(NPV < $0)	22%	
Probability of loss	22%	



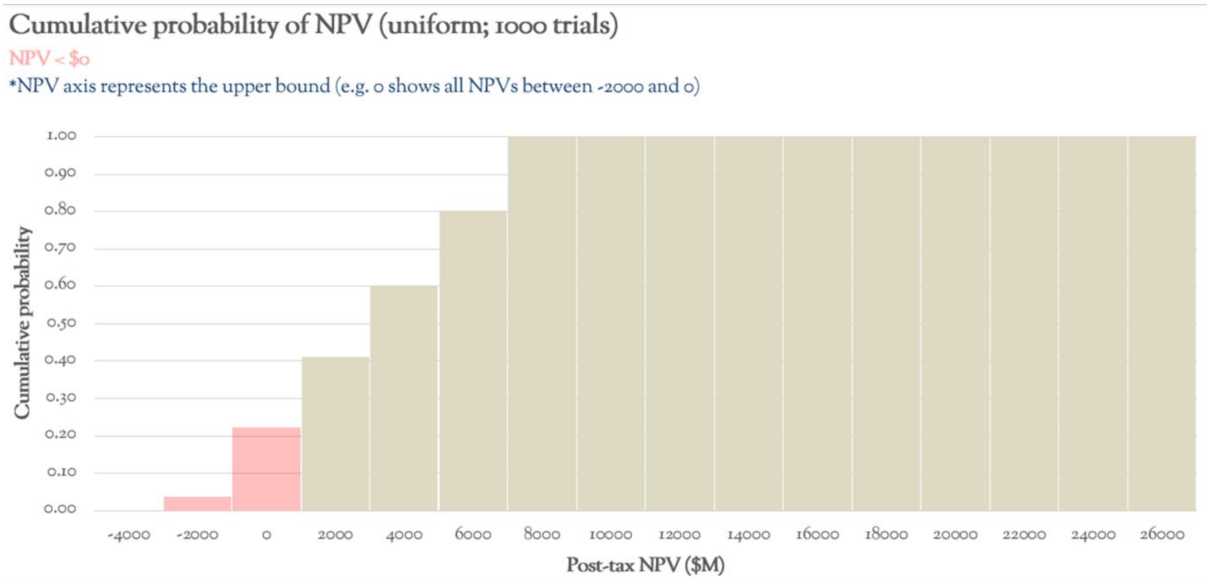
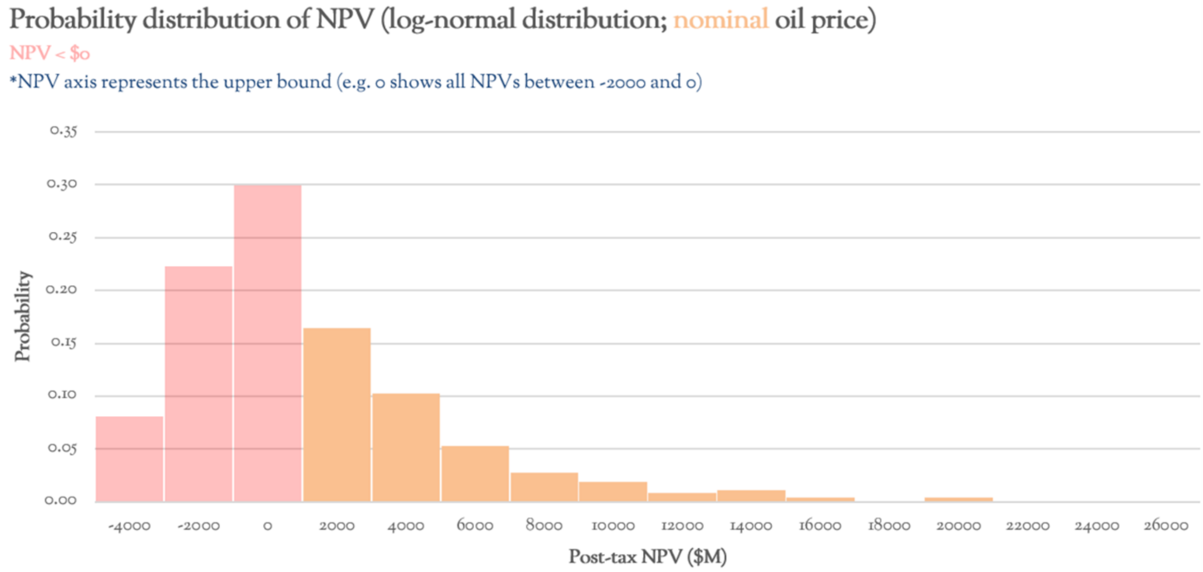


Figure 11. Summary statistics and probability distribution of the uniform model showing the effect of 1000 randomly drawn oil prices on NPV.

Log-normal model (nominal price)

Summary statistics	Oil price	NPV ($M)
Mean	39.78	103.6
Median	31.00	-789.8
99th percentile	100.79	13228.7
75th percentile	49.90	1608.4
25th percentile	20.12	-2470.7
1st percentile	6.06	-5105.7
Maximum	211.06	21308.2
Minimum	4.15	-5462.8
Sample size	1000	
P(oil price < $30/bbl)	48%	
P(NPV < $0)	60%	
Probability of loss	60%	



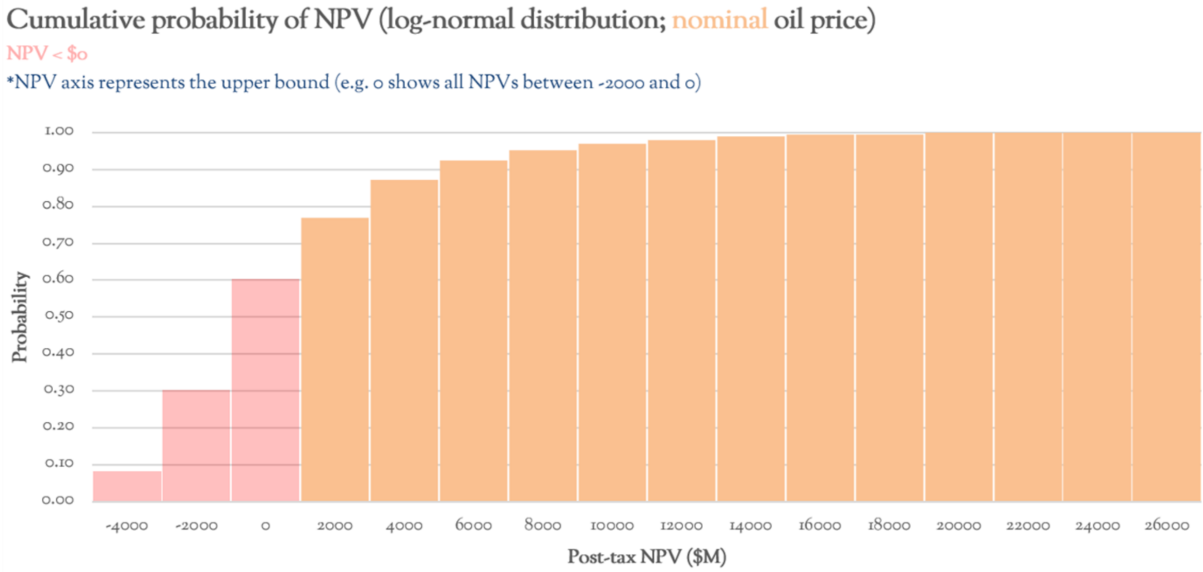
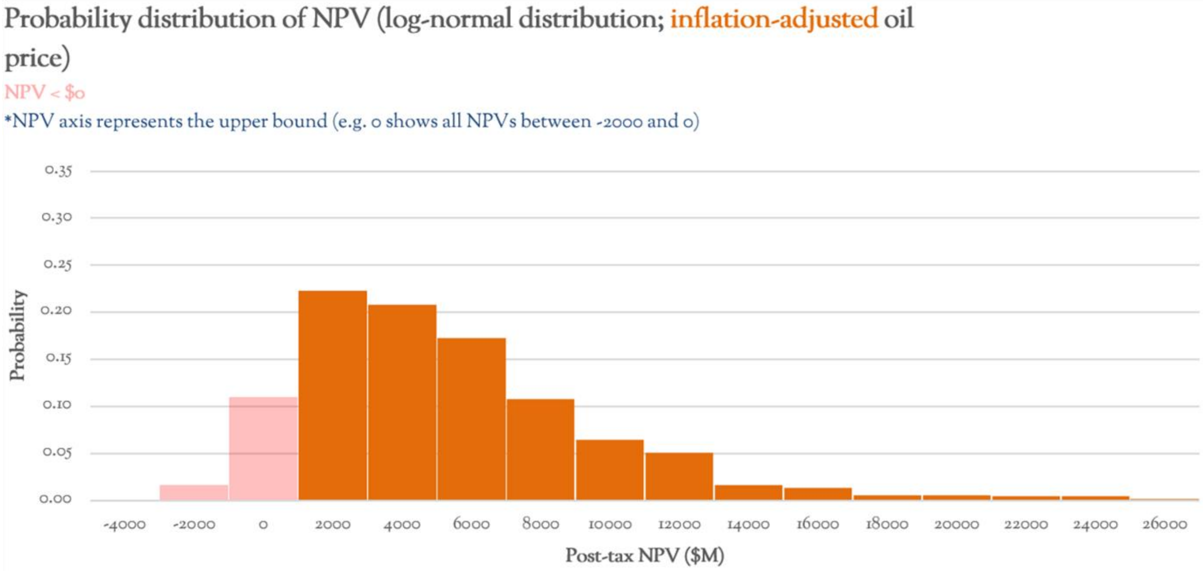


Figure 12. Summary statistics and probability distribution of the log-normal nominal model showing the effect of 1000 randomly drawn oil prices on NPV.

Log-normal model (inflation-adjusted price)

Summary statistics	Oil price	NPV ($M)
Mean	71.61	4255.0
Median	64.56	3417.4
99th percentile	192.42	19037.3
75th percentile	88.63	6364.4
25th percentile	45.75	1089.2
1st percentile	21.96	-2126.1
Maximum	245.29	25477.3
Minimum	13.46	-3719.7
Sample size	1000	
P(oil price < $30/bbl)	6%	
P(NPV < $0)	13%	
Probability of loss	13%	



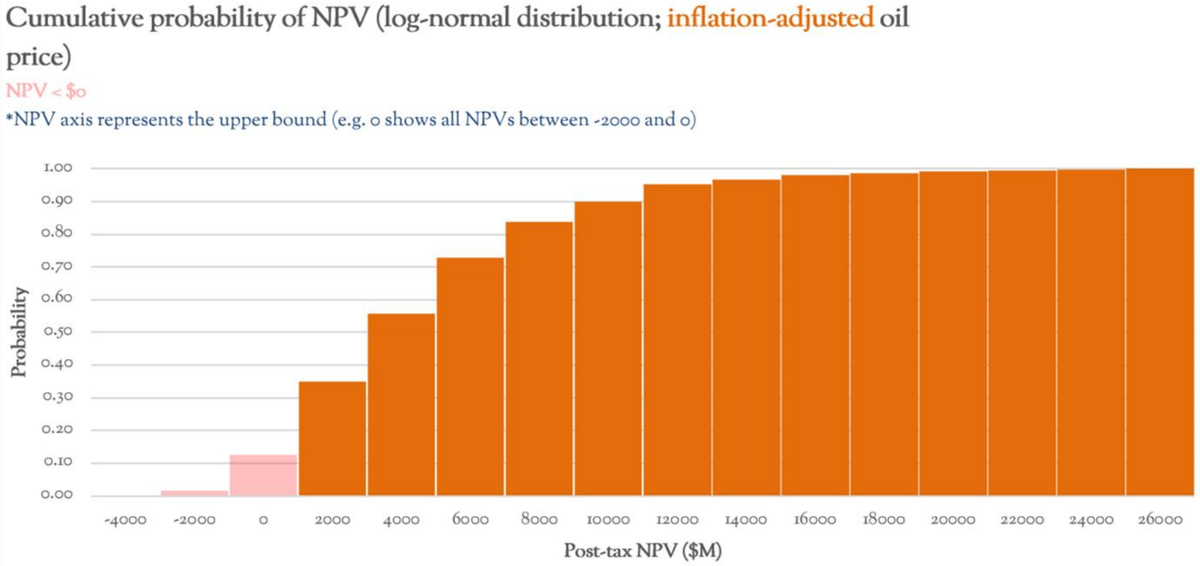


Figure 13. Summary statistics and probability distribution of the log-normal inflation-adjusted model showing the effect of 1000 randomly drawn oil prices on NPV.

Discussion

The results of the fixed inputs model suggest a positive NPV and therefore a decision to proceed with the project.

This is positive but misleading. An estimated post-tax NPV of around $2860 million suggests that the project is viable (NPV > $0), but with no probability distribution attached to any of the variables, it's hard to know how likely an investor is to have a positive NPV.

The sensitivity analysis adds some clarity: it shows that oil price is most influential to NPV, with a 40% drop from the base case ($60) enough to make the project unviable (see Figure 7/8). The scenario analysis shows that even if all of inputs dropped by 10% at the same time, the project would still be comfortably profitable (see Figure 10).

Given the importance of oil price to NPV, the assumptions underlying the Monte Carlo simulations are important, and lead to considerably different conclusions.

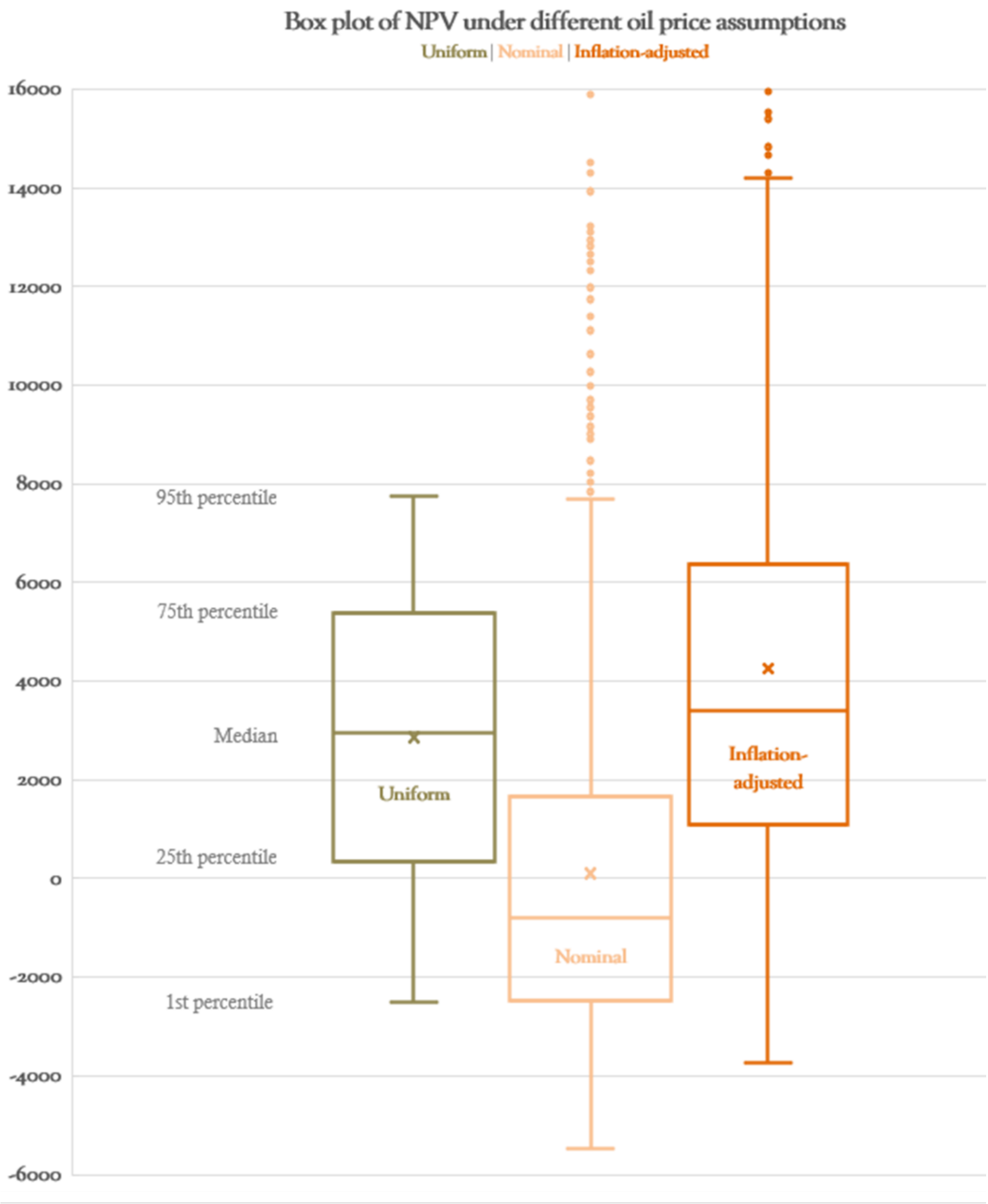


Figure 14. Box plot of the variation in NPV between different models.

Figure 14 above shows that the percentage of trials with an NPV < $0 is below the 25% in both uniform and inflation-adjusted models (22% and 13%, respectively), but for the nominal model the percentage is higher than 60%. If the probability of a loss is higher than 50%, it may be wise not to invest in the project (although the mean NPV > $0 for the nominal model, so it depends on risk preference). If I were to base my decision on the results of the uniform distribution, I would proceed with the project.

I assume that a uniform distribution is unwise because historical price data (see Figure 3) shows that oil prices follow a log-normal distribution, and I assume that a distribution based on nominal price data is also unwise, because the purchasing power of $1 in 1974 is much greater than in 2024. Therefore, if I assume that the most accurate estimation of future oil prices is the inflation-adjusted log-normal model, **my recommendation is to proceed with the project.**

Recommendations

- Proceed with the project based on available information.
- Investigate the effect of a random walk on oil prices over time and the resulting NPV.
- Run a multivariate Monte Carlo simulation to include development expenditure (assuming a triangular distribution)

Limitations

- Log-normal models simulate base oil price using past data, which assumes consistent oil market fundamentals through time. These assumptions may not hold in the next 25 years.
- A lack of data on probability distributions and covariance between inputs prevents more realistic modelling.

References

United States Energy Information Agency (EIA)., 2024. Short-Term Energy Outlook Real and Nominal Prices, April 2024. Available at: https://www.eia.gov/outlooks/steo/realprices/real_prices.xlsx

Thomopoulos, N.T., 2012. *Essentials of Monte Carlo simulation: Statistical methods for building simulation models*. Springer Science & Business Media.