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EVALUATING OIL AND GAS ASSETS: OPTION PRICING METHODS PROVE NO PANACEA

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Abstract

The authors examine the validity of using option pricing theory methods to value oil and gas assets by comparing the value of discounted cash flow and option pricing methods for an actual Gulf of Mexico oil well. Option pricing method assumptions yield questionable valuation results for real, as opposed to financial, options. In fact, as a general rule, the further upstream the oil and gas asset is, the more the option pricing method assumptions may be questioned. Therefore, careful consideration should be given to any strategic decisions based on option pricing valuations.

INTRODUCTION

Black and Scholes (1973) published what is now known as the Black-Scholes option pricing model (BSOPM) for pricing European options.[1] The BSOPM and each of its variants incorporates some specific assumption(s) regarding the uncertain movements of the financial asset price, X, through time and requires that the parameters defining those movements be known.

This paper uses the BSOPM to value an oil and gas asset and compares these values with traditional NPV valuations. The bottom line is that option valuation leads to greater values than NPV valuations. Hence, option valuation analysis would lead to "accept" decisions more often – *whether the decision is valid or not*.[2]

Just like financial assets, oil and gas assets are characteristically beset with large uncertainties affecting their values. The popularity (and success) of option theory algorithms applied to financial options led, no doubt, to wide interest in analogous application to evaluation of oil and gas assets.

OPTION THEORY FOR OIL AND GAS ASSET VALUATION

Oil and gas assets exist when there is a perception that one can make money if an exploration well were drilled on searchable property. The holder of that asset has many options; such as to drill an exploration well as soon as possible, defer drilling, or sell the searchable asset. If drilling yields a developable find, there are more options; the most likely ones being to develop the field now, later, or never.

Development into a producing field transforms the asset into one with further options such as the speed of oil recovery. Eventually, the field will revert to an irreversible decline when the only options are whether or not to shut-in and abandon the asset and, if so, when.

Each of the many options that arise in an oil and gas assets' lifetime constitutes an opportunity to make decisions based upon perceptions *at the time the option may or may not be exercised*. Just as an oil and gas assets' underlying character changes with time, the infrastructure in which the changing asset exists can also change.

That change makes consideration of all significant options that arise during an oil and gas assets' lifetime important. Capen (1991) emphasizes this principle that decisions about oil and gas assets should be driven by values prevailing at the time of the decisions. Option theory methods seek to implement that principle.

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LITERATURE REVIEW

A substantial literature exist to address option theory valuation methods for searchable, developable, and producible oil and gas assets.[3] One must recognize that oil and gas assets are not purely financial assets. Sick (1990) carefully differentiates between what he calls financial-like options, such as those related to oil and gas prices, and non-financial or real options. Oil and gas price options are akin to financial options in the stock market because profits due to higher prices are not limited, but losses due to lower prices are bounded at zero.[4] Therefore, with reasonably symmetrical price uncertainties, option theory valuations will be higher than otherwise for oil and gas assets just like financial assets. Further, the greater the uncertainties, ceteris paribus, the greater the increased option valuations.

Option theory methods for oil and gas assets in the literature seem preoccupied with concern about the affect of future, uncertain oil and gas prices and, less so, on the non-financial options involved. Ekern (1985) considers the options related to developing a satellite oil field. Stensland and Tjostheim (1991) examine the options arising as better information through time reduces uncertainties in the exploitation of development assets. Bjerksund (1991) delves into the cost of foreclosing the option to develop an oil and gas asset; Lohrenz (1991) does so with respect to shut-in and abandonment of assets.

Obviously, oil and gas assets gives rise to different net cash flows. Each net cash flow has its own uncertainties and the market reacts to the perceived uncertainties. Jacoby and Laughton (1992) give an option theory valuation methodology that considers each of the cost, net revenue, and tax cash flows and their unique uncertainties. The claimed advantage for their methodology is the ability to define the different risks associated through time for the investor and the taxing government.

OPTION THEORY VS DISCOUNTED CASH FLOW

Literature often touts option theory methods as an improvement over traditional discounted cash flow (DCF) methods. Admittedly, DCF methods unavoidably invoke burdening assumptions - often unstated. Ingersoll and Ross (1992) note “that in deciding to take an investment by looking at only its NPV, the standard textbook solution tacitly assumes that doing so will in no way affect other investment opportunities.” They further note that “even for the simplest projects with deterministic cash flows, interest-rate uncertainty has a significant effect on investment. While uncertain changes in cash flows and learning can cause some projects to be delayed, the effect of the interest rate is ubiquitous and critical to understanding investment at the macroeconomic level. In particular, then, even naïve investors who ignore the embedded options in their projects and use simple certainty equivalent cash flow projections may well be sensitive to options inherent in possible changes in financing costs.”

What Ingersoll and Ross point out, of course, is traditional DCF methods’ blindness to uncertain happenstance, favorable and not, that provide potentially exploitable future decision options.

Markland (1992) ascribes a specific advantage of option theory method in that it “brings with it a bonus; the choice of discount rate now becomes redundant.” If one holds that the proper discount rate is the marginal cost of capital in the market for the asset in question *that prevails at the time of the decision option*, then any method which avoids having to make such a choice is attractive. However, this bonus presumes the ability to quantitatively describe the option’s uncertainties, thus allowing option theory methods use.

Option theory methods seek to overcome these burdens inherent in traditional DCF methods and prove advantageous to the extent the methods do so.

This paper compares DCF and option pricing methods for an actual Gulf of Mexico oil and gas asset encompassing the searchable, developable, and producible phases. The authors examine key decisions driven by DCF methods made during the life of this asset and then examine this same asset using the BSOPM.

THE LIFE OF AN ACTUAL OIL AND GAS ASSET

Table 1 shows the annual net cash flows (ANCFs) for the entire life of the oil and gas asset starting with its searchable status in 1960 and terminating in 1987 with the project’s abandonment. Consolidating oil and gas revenues simplifies the analyses. Table 1 clearly shows the oil price increases circa 1974 and 1979.

TABLE 1
Actual Annual Net Cash Flow Table For The Life Of An Oil And Gas Asset
(All Figures Are In $ Millions Except As Noted)

Year	Oil Price $/bbl	Annual Production (MM bbl)	Gross Revenue	Royalties	Capital Costs	Operating Costs	Before Tax ANCF[1]	Taxes	Producer Price Index[2]
1960	2.88	0.0	0.00	0.00	2.5	4.0	-6.50	-2.09	100.0
1961	2.88	0.0	0.00	0.00	0.0	0.1	-0.10	-0.21	99.6
1962	2.88	0.0	0.00	0.00	0.0	0.2	-0.15	-0.24	99.9
1963	2.88	0.0	0.00	0.00	0.5	0.1	-0.60	-0.25	99.6
1964	2.88	0.0	0.00	0.00	13.0	0.6	-13.60	-1.38	99.8
1965	2.86	0.9	2.57	0.42	15.5	0.5	-13.85	-1.37	101.8
1966	2.86	3.3	9.44	1.57	16.0	1.8	-9.93	-0.34	105.2
1967	2.86	5.0	14.30	2.38	3.0	2.8	6.12	1.08	105.4
1968	2.86	5.6	16.02	2.66	0.8	3.2	9.36	1.52	108.0
1969	2.86	6.7	19.16	6.19	1.0	3.6	8.37	2.52	112.2
1970	3.18	5.6	17.81	2.96	0.0	3.5	11.35	2.06	116.3
1971	3.39	5.0	16.95	2.82	0.0	3.2	10.93	2.75	120.0
1972	3.39	5.5	18.65	3.10	0.4	3.6	11.55	4.27	125.5
1973	3.96	4.8	19.01	3.16	0.2	3.8	11.85	5.40	141.9
1974	6.88	6.0	41.28	6.88	0.0	3.9	30.50	14.47	168.7
1975	7.67	4.1	31.45	5.24	0.0	6.2	20.01	9.49	194.3
1976	8.19	3.9	31.94	5.32	0.0	5.8	20.82	9.95	192.7
1977	8.57	3.2	27.42	4.57	0.0	5.4	17.45	8.33	204.6
1978	9.00	3.1	27.90	4.65	0.0	2.8	20.45	9.77	220.5
1979	13.99	2.4	33.58	5.59	0.0	3.6	24.39	11.68	248.3
1980	22.49	1.8	40.48	6.74	2.0	8.0	23.74	12.21	283.1
1981	31.13	1.0	31.13	5.18	2.1	6.0	17.85	9.29	309.1
1982	28.52	0.2	5.70	0.95	0.0	3.0	1.75	0.56	315.4
1983	26.19	0.3	7.86	1.31	0.0	1.5	5.05	2.14	319.4
1984	25.88	0.1	2.59	0.43	0.0	0.4	1.76	0.56	327.0
1985	23.95	0.1	1.19	0.20	0.0	0.3	0.69	0.05	325.4
1986	11.36	0.0	0.22	0.03	0.0	0.3	-0.11	-0.33	317.1
1987	15.40	0.0	0.15	0.02	0.0	5.2	-5.07	-2.57	329.9
		68.6	416.79	72.37	57.0	83.4	204.07	99.32	

1. ANCF = Annual Net Cash Flow
2. 1960 = 100.0

The asset produced 68.6 million barrels of oil through its life and, after deducting royalties paid, operating costs, and all capital costs, showed a profit of $204.7 million before taxes. Taxes totaled $99 million over the project's life, thus yielding an after-tax profit of $108 million. Converting the previous figures from nominal dollar terms to real dollar terms yields an aggregate after-tax, real dollar profit of $50 million.

Table 1 reflects the major events during the asset's life. The operator, believing a searchable asset existed, spent $6.5 million ($2.5 million capital plus $4.0 million operating costs) in 1960 to acquire drilling rights. Tests led the operator to perceive that a developable asset existed circa 1964. The operator exercised the option to develop the asset investing $44.5 million from 1964 through 1966. Minor production commenced during 1965, but substantial production began in 1966.

The project's oil production rose rapidly to annual rates of about 6 million barrels per year and maintained that level for almost a decade. Decline followed in typical fashion. Table 1 shows a total of $4.1 million in capital investments made in 1980-81 to try to arrest decline, but abandonment came in 1987 (abandonment costs included in the year's $5.2 million operating costs).

Table 2 shows the actual internal rates of return (IRR) for this project at various stages for both nominal and real net, before-tax and after-tax cash flows.[5] The after-tax, real IRRs range from 10.2% from the searchable stage to 160.8% for the producible stage.

TABLE 2
Internal Rates Of Return For The Life Of An Oil And Gas Asset

Type Of Asset:	Searchable	Developable	Producible
Before-Tax, Nominal	17.0%	21.6%	164.9%
Before-Tax, Real	12.9%	17.2%	162.6%
After-Tax, Nominal	14.2%	17.2%	163.2%
After-Tax, Real	10.2%	12.6%	160.8%

DCF EVALUATION

A record of the investment's decisions using DCF methods follows. This record is essentially anecdotal and includes simplifying assumptions.

The decision to acquire the rights and drill the wildcat well for this asset assumed that a lump sum exploration cost of $6.5 million at time t=0 would be followed by a lump sum development cost of $40 million at time t=2 years. The assumed returns were nominal ANCFs (before taxes) of $36 million per year from time t=3 years to t=15 years. There was no consideration of abandonment costs. The net ANCFs assumed a production rate of 16.7 million barrels per year at a constant price of $2.88 less one-sixth royalty and operating costs of 10% of gross revenue. This projection estimated 200 million barrels of recoverable reserves. Using continuous compounding, the NPV of this searchable assets is:

$$-6.5 - 40\,exp(-2i) + 36\int_{t=3}^{15} exp(-it)\,dt$$

where i is the annual discount rate. Using discount rates of 15%, 25%, and 35% (the last appearing to be the actual hurdle rate used) yields NPVs of $91.6 million, $33.9 million, and $9.1 million, respectively. The IRR for these cash flows is 42.4%.

No record of a specific consideration of the risk of failure exists. Presumably, consideration of appropriate risks occurred in the selection of the hurdle rate.[6]

The wildcat well was successful. The decision to develop, of course, included the additional information available three years after exploration began. Estimated recoverable reserves were now 100 million barrels. Estimated lump sum developmental costs at time t=0 were $45 million with before-tax ANCFs of $18 million from t=1 year to t=13 years. Again, no consideration of abandonment costs existed. Thus, the NPV of the developable asset is:

$$-45 + 18\int_{t=1}^{13} exp(-it)dt$$

The effective hurdle rate appears to have been 25% at which the NPV is $8.3 million. The IRR is 29.0%. These projections provided the justification for proceeding with the project.

In fact, the actual after-tax, real ANCFs did not meet the 25% hurdle rate as can be seen in Table 2.[7] Clearly, the actual project did not perform as well as planned.

BSOPM EVALUATION

Now, the authors analyze the same project using the BSOPM. Note that the BSOPM considers a European option that can only be exercised at maturity. Jarrow and Rudd (1983) among others show that an American (allowing early exercise) option's value is equal to or greater than an European option's. Therefore, this method biases the results to achieve minimum values.[8]

In 1960, after paying a bonus of $2 million for a lease with a 5-year term, the operator had an option to drill a wildcat well costing $4.5 million. At that time, the perceived market value of the searchable asset was $15.6 million.[9]

In the context of the BSOPM, x=15.6, c=4.5, and T=5. For the development option, the operator has the option of paying $45 million in 1963 for a developable asset then valued at $53.3 million.[10] Here, x=53.3, c=45, and T=2 because the option expires in 1965.

At this point, two important input decisions must be made: what is the proper risk-free interest rate? and what is the proper variance of the rate of change of the oil and gas asset in question? To provide a wide range of possibilities the authors use r = 0% and r = 8% based on the findings of Lohrenz (1991), who shows the market interest rate for fully developed, declining production oil and gas assets to be about 8% per year and Paddock, Siegel, and Smith (1988) who use 1.25% per year.

Now, what is the actual variance for oil and gas asset wildcat well and development options? While seeking a defensible common sense answer to the above question, one must confront another, more important question: Do oil and gas asset values fluctuate through time in a random Brownian movement quantified by the single parameter, σ^2, as prescribed by the BSOPM? From all that is known about scenarios which make significant changes in the values of oil and gas assets through time, the indicated answer is no.

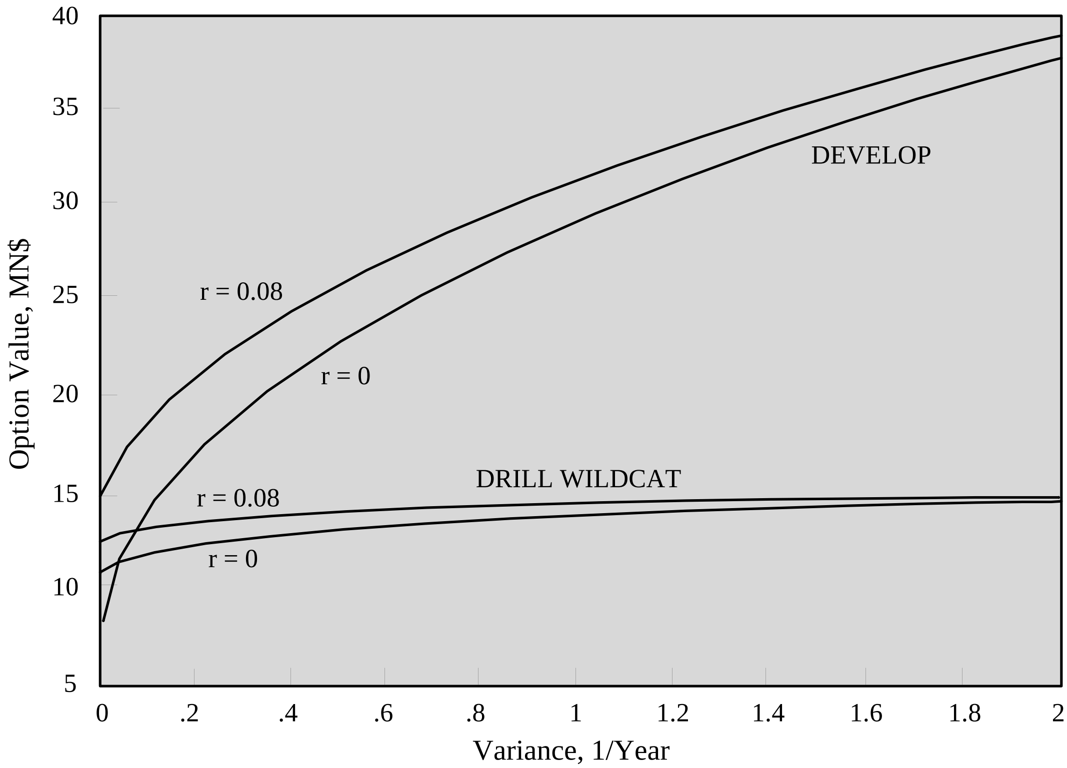
The upside risks of oil and gas assets; such as reserves being greater than expected or technological improvements increasing recoverable reserves, have downside analogs limited to zero recoverable reserves. However, there are other downside risks, some of which may transform the asset into a virtually limitless liability. Such risks include: unfavorable regulatory changes, court decisions, and environmental catastrophe.

One can quantitatively estimate a variance to the extent that the values of real oil and gas assets depend solely on oil and gas prices. Paddock, Siegel, and Smith (1988) use this method and find representative values of σ^2 = 2.02% and 6.25% per year. These variances only attempt to quantify asset value variation due to oil price changes and not the added upside and downside risks discussed above. Variances which consider these additional risks would reasonably be much higher. Not knowing the proper variance rate, the authors use values for σ^2 from 0% to 200%, inclusive in calculating option values.

Figure 1 shows the values for the searchable ("Drill Wildcat") and developable ("Develop") asset stages for r = 0% and r = 8% and σ^2 = 0% and σ^2 = 200% using the BSOPM.[11]

Remember that the DCF methods yielded NPVs of $9.1 million and $8.3 million for the searchable and developable assets, respectively. The values from the BSOPM are *greater* than the DCF values. This condition is the basis of assertions that the option theory methods "see" values that traditional DCF methods miss. Lehman (1989) writes that DCF analysis "tends to undervalue real investments." Burns, Lewis, and Sick (1992) write "Conventional discounted cash flow methods significantly undervalue investment opportunities which appear in nominal or non-economic at current product prices, but which may be delayed at low cost." They further write that "in the option context increased price volatility leads to a high project value because the option value reflects the limited downside risk while allowing upside gain."

FIGURE 1



The assertions are correct for assets with values subject only to the effects of the oil and gas price fluctuations, but are not necessarily correct and may be horrendously in error for real oil and gas asset values. One must be wary of all methods which serve the bias of owners to achieve higher valuations for their oil and gas properties.[12]

In general, option valuation methods would be more appropriate for oil and gas assets the further downstream the investment. As such, fully developed, declining producing properties would be the best candidates for the application of option pricing methods. However, even here, owners should consider the virtually limitless cost of potential environmental problems.

CONCLUSION

This paper uses an actual oil and gas asset and the values derived from traditional DCF methods in comparison with BSOPM values. This process shows that "it makes little sense to use a numerical technique to calculate the option price accurate to 1% or 2% when the underlying asset price is only known to an accuracy of 10%, as in real options" (Sick (1990)).

Neither option theory nor the world's most complete stochastic tree can untwine the "Catch 22" in quantitative analysis of uncertainties that affect outcome. First, uncertainty analysis is a reaction to the recognition that there are uncertainties in the parameters used to estimate the outcomes. However, analysts must then allow sufficient knowledge such that uncertainties can be characterized and quantified. Thus, after first admitting ignorance in the first step, analysts suddenly undertake to having great wisdom in the second.

The authors' certainly do not believe that this problem invalidates option theory or other methodologies analyzing outcomes. Benefits arise from critically examining any and all uncertainties affecting outcomes. Meanwhile, results from uncertainty analysis should be tempered knowing that the real world and its real uncertainties have not been captured – only modeled by necessarily flawed and incomplete practice and practitioners.

ENDNOTES

1. The familiar model being: $w(X,t) = XN(d_1) - c\, e^{-rT}N(d_2)$

   where:

   $N(\,)$ = the cumulative normal density function
   $d_1 = \{ln(x/c) + (r + 0.5\sigma^2)(T)\} / \{\sigma(T)^{0.5}\}$
   $d_2 = d_1 - \sigma(T)^{0.5}$
   $w(X,t)$ = the value of an European call option
   X = the value of underlying asset
   c = the exercise price
   r = the risk-free rate of interest
   T = the time to maturity (t^*-t)
   σ^2 = the variance of the rate of return of the underlying asset, X

   Inherent assumptions of the model include that the stock price fluctuates in random Brownian movements (Wiener process), the stock pays no dividends, and the option can not be exercised until maturity (European option.)

2. A potential objection to this study is that it analyzes a "failed" project. In fact, the investing company considered the project a huge success (as demonstrated by a lavish party celebrating its production history.) This project is chosen specifically to exhibit that the most sophisticated models perform little better or worse than simpler ones when the information used is incomplete and/or inaccurate.

3. See for example: Banks (1987), Bjerksund (1991), Brennan and Schwartz (1985), Burns, Lewis and Sick (1992), Ekern (1985), Gibson and Schwartz (1991), Jacoby and Laughton (1992), Laughton and Jacoby (1991), Lehman (1989), Lorenz (1991), Mann, Goobie and MacMillan (1992), Markland (1992), Paddlock, Siegel and Smith (1988), Rosenthal (1988), Sick (1990), Siegel, Smith and Paddock (1987) and Stensland and Tjostheim (1991) to provide a representative, but only partial list.

4. The preceding assumes that one is "long" in the underlying asset, of course.

5. All DCF methods assume each ANCF occurred as a mid-year lump sum with continuous discounting.

6. One can easily calculate that for E(NPV) = 0 for the wildcat well and the subsequent development of the project, the risk of failure can be as high as 93%, 84% and 42% at discount rates of 15%, 25% and 35%, respectively. Historically, about one-third of all wildcat wells were successful in this area (Lohrenz (1988)). Thus, for a searchable asset, the planned wildcat well project was easily justified.

7. At the discount rate of 25%, actual searchable and developable asset NPVs were -\$8.4 million and -\$4.7 million, respectively.

8. The bottom line of the comparison between DCF and BSOPM methods is if either provides a more accurate asset valuation *given information available when investment decisions are made*. Therefore, biasing the option valuation method to be its lowest is important given the actual value of the project versus its expected value.

9. The $15.6 million equals the $6.5 million bonus and wildcat well costs incurred in 1960 plus the NPV of $9.1 million at the hurdle discount rate of 35%.

10. $45 million development cost plus the NPV of $8.3 million at the hurdle rate of 25%.

11. Note that the expected positive relationship between the option's value and r and σ^2 exists (see Galai and Masulis (1976)).

12. As always, one should be skeptical of any valuation method that is touted as providing a "higher" valuation than other methods. What is desired is the "true" value, not the "highest" value of an asset.

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